From:	Maloney, Kelsey
To:	Maloney, Kelsey; Gibbons, Dayna; Frithsen, Jeff; Matthews, Lisa; Briskin, Jeanne; Smith, Kelley; Perry, Dale; Hubbard, Carolyn; Burke, Thomas; Bueno, Michael
CC:	Allen, Laura; Purchia, Liz; Valentine, Julia; Hull, George; Milbourn, Cathy; Teichman, Kevin; Simunek, Diane; Ridley, Caroline
Sent:	6/2/2015 2:45:09 PM
Subject:	HF Study Draft Assessment Public Webinar - 2

From:	Maloney, Kelsey
To:	Maloney, Kelsey; Gibbons, Dayna; Frithsen, Jeff; Matthews, Lisa; Briskin, Jeanne; Smith, Kelley; Perry, Dale; Hubbard, Carolyn; Burke, Thomas; Bueno, Michael
CC:	Allen, Laura; Purchia, Liz; Valentine, Julia; Hull, George; Milbourn, Cathy; Teichman, Kevin; Simunek, Diane; Ridley, Caroline
Sent:	6/2/2015 2:42:26 PM
Subject:	HF Study Draft Assessment Public Webinar - 1

Hi all—we will be in Hurd Hall (41102 RRB) for the draft assessment public webinars on Friday.

From:	Matthews, Lisa
To:	Allen, Laura
Sent:	5/18/2015 9:40:28 AM
Subject:	Accepted: Chat about HF Case Studies messaging

From:	Hubbard, Carolyn
To:	Allen, Laura
Sent:	5/18/2015 9:37:53 AM
Subject:	Accepted: Chat about HF Case Studies messaging

From:	Hubbard, Carolyn
To:	Allen, Laura
Sent:	5/15/2015 1:53:24 PM
Subject:	Accepted: Chat about HF Case Studies messaging

From:	Matthews, Lisa
To:	Allen, Laura
Sent:	5/15/2015 12:29:30 PM
Subject:	Accepted: Chat about HF Case Studies messaging

From: Perry, Dale
To: Allen, Laura
Sent: 5/15/2015 11:56:54 AM
Subject: Tentative: Chat about HF Case Studies messaging

Liz and I have a meeting with NGA at that time (with their press folks) to talk about the assessment but as long as you and Dayna are there I don't think it's critical for us to be in the room.

From:	Maloney, Kelsey
To:	Maloney, Kelsey; Gibbons, Dayna; Frithsen, Jeff; Matthews, Lisa; Briskin, Jeanne; Smith, Kelley; Perry, Dale; Hubbard, Carolyn; Burke, Thomas; Bueno, Michael
CC:	Allen, Laura; Purchia, Liz; Valentine, Julia; Hull, George; Milbourn, Cathy; Teichman, Kevin; Simunek, Diane; Ridley, Caroline
Sent:	6/2/2015 2:42:26 PM
Subject:	HF Study Draft Assessment Public Webinar - 1

Hi all—we will be in Hurd Hall (41102 RRB) for the draft assessment public webinars on Friday.

From:	Briskin, Jeanne
To:	Maloney, Kelsey
Sent:	6/2/2015 2:45:26 PM
Subject:	Accepted: HF Study Draft Assessment Public Webinar - 2

From: Briskin, Jeanne
To: Maloney, Kelsey
Sent: 6/2/2015 2:43:22 PM
Subject: Accepted: HF Study Draft Assessment Public Webinar - 1

From:	Briskin, Jeanne on behalf of Burden, Susan
To:	Susan Burden (Burden.Susan@epa.gov)
Sent:	6/2/2015 10:00:30 AM
Subject:	FW: HF Team Meeting

Now that the assessment is going out should we cancel future team meetings?

-----Original Appointment-----
From: Burden, Susan
Sent: Thursday, April 23, 2015 8:18 AM
To: Burden, Susan; Briskin, Jeanne; Daiss, Rebecca; Gibbons, Dayna; Matthews, Lisa; Roberts, Cindy; Sharkey, Susan; Tinsley, Chuck; Watkins, Stephen; Wiser, Nathan; Frithsen, Jeff; LeDuc, Stephen; Cluff, Maryam; Singer, Alison; Williams, Larke; Bueno, Michael; Fleming, Megan; Ridley, Caroline; Maloney, Kelsey
Subject: HF Team Meeting
When: Occurs every Tuesday effective 4/28/2015 until 12/29/2015 from 11:00 AM to 12:00 PM (UTC-05:00) Eastern Time (US & Canada).
Where: DCRoomRRB51161

Ex. 6

From:	Briskin, Jeanne on behalf of Phillips, Anna
To:	Gibbons, Dayna
Sent:	5/27/2015 10:07:40 AM
Subject:	FW: HF Assessment Outreach

To talk about how to provide updates on the HF research and assessment to the international audiences.

Dayna,

Feel free to stop by my office for the call. Anna, we can also come to your desk to talk in person if you prefer.

Jeanne

-----Original Appointment-----
From: Phillips, Anna
Sent: Tuesday, May 26, 2015 6:54 PM
To: Phillips, Anna; Briskin, Jeanne
Subject: HF Assessment Outreach
When: Wednesday, May 27, 2015 12:30 PM-12:30 PM (UTC-05:00) Eastern Time (US & Canada).
Where:

We probably won't need the full 30 minutes but just in case...

From: Gentry, Nathan on behalf of Burke, Thomas
To: Burke, Thomas
Sent: 6/9/2015 4:52:03 PM
Subject: CBC Radio Interview

On Jun 9, 2015, at 3:49 PM, Allen, Laura <Allen.Laura@epa.gov> wrote:

Hey all- CBC radio (Canadian Broadcasting Corporation- basically Canadian public radio) want to do a taped interview- less than 10 minutes- to discuss the HF assessment. They want to focus on what info we reviewed and our findings. The producer mentioned that they are headquartered in New Brunswick (where there is a fracking moratorium). I mentioned our expert would only focus on the study, and not be able to address local issues. Interview would be conducted by the morning show host, Terry Seguin.

More on the show: http://www.cbc.ca/informationmorningfredericton/

They want to set this up tomorrow between 9 and 11am. Can you let me know if that would be possible for Tom's schedule?

Thank you!

From:	Maloney, Kelsey
To:	Maloney, Kelsey; Gibbons, Dayna; Frithsen, Jeff; Matthews, Lisa; Briskin, Jeanne; Smith, Kelley; Perry, Dale; Hubbard, Carolyn; Burke, Thomas; Bueno, Michael
CC:	Allen, Laura; Purchia, Liz; Valentine, Julia; Hull, George; Milbourn, Cathy; Teichman, Kevin; Simunek, Diane; Ridley, Caroline
Sent:	6/2/2015 2:45:10 PM
Subject:	HF Study Draft Assessment Public Webinar - 2

From:	Maloney, Kelsey
To:	Gibbons, Dayna; Frithsen, Jeff; Matthews, Lisa; Briskin, Jeanne; Smith, Kelley; Perry, Dale; Hubbard, Carolyn; Burke, Thomas; Bueno, Michael
CC:	Allen, Laura; Purchia, Liz; Valentine, Julia; Hull, George; Milbourn, Cathy; Teichman, Kevin; Simunek, Diane; Ridley, Caroline
Sent:	6/2/2015 2:45:07 PM
Subject:	HF Study Draft Assessment Public Webinar - 2

From:	Gibbons, Dayna
To:	Burke, Thomas
Sent:	5/7/2015 4:34:33 PM
Subject:	Accepted: HOLD: Possible last chance time for in person HF Retrospective or HF DW Study messaging or presentation Discussion time

From: Gibbons, Dayna
To: Burke, Thomas
Sent: 3/27/2015 1:34:22 PM
Subject: Accepted: HF Drinking Water Chapter Comments: Executive Summary & chapters 6-10 (Discussion part 1)

From: Gibbons, Dayna
To: Burke, Thomas
Sent: 3/27/2015 1:06:57 PM
Subject: Accepted: HF Drinking Water Chapter Comments: Chapter 4

From: Gibbons, Dayna
To: Burke, Thomas
Sent: 3/27/2015 1:03:52 PM
Subject: Accepted: HF Drinking Water Chapter Comments: Executive Summary & chapters 6-10 (Discussion part 1)

From: Gibbons, Dayna
To: Burke, Thomas
Sent: 3/27/2015 1:03:48 PM
Subject: Accepted: HF Drinking Water Chapter Comments: Executive Summary & chapters 6-10 (Discussion part 2 - if needed)

From:	Gibbons, Dayna
To:	Burke, Thomas
Sent:	3/27/2015 12:57:49 PM
Subject:	Accepted: HF Drinking Water Chapter Comments: 1,2,3, and 5

From:	Piantanida, David
To:	Piantanida, David; Frithsen, Jeff; Gibbons, Dayna; Linkins, Samantha; Levine, Carolyn; Janifer, Pamela
Sent:	6/17/2015 4:24:51 PM
Subject:	Draft Assessment on the potential impacts to DW resources from HF Activities

Ex. 5

Thanks,

-David Piantanida

Also, the briefing will be in room 2123 Rayburn House Office Building. Pamela said they expect a good number of staffers to attend, possibly around 30 people.

Samantha Linkins
Science Communication
Office of Research and Development, US EPA
Washington, DC
Office: 202-564-1834
Ex. 6

We are going to take a cab up with Pamela Jannifer tomorrow morning. We'll meet 9:30 at 13th and Penn.

From:	Maloney, Kelsey
To:	Maloney, Kelsey; Ridley, Caroline; LeDuc, Stephen; Frithsen, Jeff; Gibbons, Dayna; Bueno, Michael; Matthews, Lisa; Briskin, Jeanne
Sent:	6/5/2015 4:41:14 PM
Subject:	EPA employee webinar on the draft assessment

Hold for EPA employee webinar on Tuesday, June 9th at 2pm.

From: Frithsen, Jeff
To: Frithsen, Jeff
Sent: 6/4/2015 6:17:25 PM
Subject: HFDWA: Approps staffers briefing

From: Piantanida, David
Sent: Thursday, June 04, 2015 5:28 PM
To: Frithsen, Jeff; Kadeli, Lek
Cc: Gibbons, Dayna; Blackburn, Elizabeth; Corona, Elizabeth; Gentry, Nathan
Subject: FW: How about 4:00 on Friday?

Importance: High

Jeff and Lek - it is set for 4:00 tomorrow as a call with the Approps. staffers. See call-in details below. Ed will not be on the call - but Jim Blizzard from OCIR will be on it - and if you want me on the call, let me know.

Ex. 6

Nathan - please block this time on their calendars.

Thanks,

David Piantanida, (202) 564-8318, **Ex. 6**

Senior Advisor

Office of Research and Development

U.S. Environmental Protection Agency

From: Walsh, Ed
Sent: Thursday, June 04, 2015 5:23 PM
To: Piantanida, David; Blizzard, James
Subject: RE: How about 4:00 on Friday?

Non-Responsive

Ex. 5

Non-Responsive

From: Piantanida, David
Sent: Thursday, June 04, 2015 2:18 PM
To: Walsh, Ed; Blizzard, James
Subject: RE: How about 4:00 on Friday?

Non-Responsive

From: Walsh, Ed
Sent: Thursday, June 04, 2015 2:18 PM
To: Piantanida, David; Blizzard, James
Subject: RE: How about 4:00 on Friday?

Non-Responsive

From: Piantanida, David
Sent: Thursday, June 04, 2015 2:17 PM
To: Walsh, Ed; Blizzard, James
Subject: RE: How about 4:00 on Friday?

Non-Responsive

David Piantanida, (202) 564-8318, Ex. 6

Senior Advisor

Office of Research and Development

U.S. Environmental Protection Agency

From: Walsh, Ed
Sent: Thursday, June 04, 2015 12:26 PM
To: Piantanida, David; Blizzard, James
Subject: RE: Final- HF Study News Release, 12 PM

Non-Responsive

From: Piantanida, David
Sent: Thursday, June 04, 2015 11:45 AM
To: Blizzard, James
Cc: Walsh, Ed
Subject: Re: Final- HF Study News Release, 12 PM

We are rarely Certain but hoping this is final.

David Piantanida, 202-564-8318

US EPA

Office of Research and Development

Ex. 6

Sent from my iPhone

On Jun 4, 2015, at 11:44 AM, Blizzard, James <Blizzard.James@epa.gov> wrote:

You sure?

From: Piantanida, David
Sent: Thursday, June 04, 2015 11:44 AM
To: Walsh, Ed
Cc: Blizzard, James
Subject: Fwd: Final- HF Study News Release, 12 PM

Here is the final release.

David Piantanida, 202-564-8318

US EPA

Office of Research and Development

Ex. 6

Sent from my iPhone

Begin forwarded message:

From: "Allen, Laura" <Allen.Laura@epa.gov>
Date: June 4, 2015 at 11:34:11 AM EDT
To: "Daguillard, Robert" <Daguillard.Robert@epa.gov>, AO OPA OMR 60 Minute Warning

<AO_OPA_OMR_60_Minute_Warning@epa.gov>
Subject: Final- HF Study News Release, 12 PM

Hi all- the final version of the press release is below and it will be sent at noon today. Thanks!

Laura Allen

Deputy Press Secretary
Office of the Administrator
U.S. Environmental Protection Agency

Email: Allen.Laura@epa.gov

Office: 202-564-1175

Ex. 6

Please consider the environment before printing this email.

Contact: (News Media Only)

Cathy Milbourn

(202) 564-7849

Ex. 6

milbourn.cathy@epa.gov

For Immediate Release

June 4th, 2015

EPA Releases Draft Assessment on the Potential Impacts to Drinking Water Resources from Hydraulic Fracturing Activities

Assessment shows hydraulic fracturing activities have not led to widespread, systemic impacts to drinking water resources and identifies important vulnerabilities to drinking water resources.

WASHINGTON—The Environmental Protection Agency (EPA) is releasing a draft assessment today on the potential impacts of hydraulic fracturing activities on drinking water resources in the United States. The assessment, done at the request of Congress, shows that while hydraulic fracturing activities in the U.S. are carried out in a way that have not led to widespread, systemic impacts on drinking water resources, there are potential vulnerabilities in the water lifecycle that could impact drinking water. The assessment follows the water used for hydraulic fracturing from water acquisition, chemical mixing at the well pad site, well injection of fracking fluids, the collection of hydraulic fracturing wastewater (including flowback and produced water), and wastewater treatment and disposal [http://www2.epa.gov/hfstudy/hydraulic-fracturing-water-cycle].

“EPA's draft assessment will give state regulators, tribes and local communities and industry around the country a critical resource to identify how best to protect public health and their drinking water resources,” said **Dr. Thomas A. Burke, EPA's Science Advisor and Deputy Assistant Administrator of EPA's Office of Research and Development.** “It is the most complete compilation of scientific data to date, including over 950 sources of information, published papers, numerous technical reports, information from stakeholders and peer-reviewed EPA scientific reports.”

EPA's review of data sources available to the agency found specific instances where well integrity and waste water management related to hydraulic fracturing activities impacted drinking water resources, but they were small compared to the large number of hydraulically fractured wells across the country. The report provides valuable information about potential vulnerabilities, some of which are not unique to hydraulic fracturing, to drinking water resources, but was not designed to be a list of documented impacts.

These vulnerabilities to drinking water resources include:

· water withdrawals in areas with low water availability;

· hydraulic fracturing conducted directly into formations containing drinking water resources;

· inadequately cased or cemented wells resulting in below ground migration of gases and liquids;

· inadequately treated wastewater discharged into drinking water resources;

· and spills of hydraulic fluids and hydraulic fracturing wastewater, including flowback and produced water.

Also released today were nine peer-reviewed EPA scientific reports (www.epa.gov/hfstudy). These reports were a part of EPA's overall hydraulic fracturing drinking water study and contributed to the findings outlined in the draft assessment. Over 20 peer-reviewed articles or reports were published as part of this study [http://www2.epa.gov/hfstudy/published-scientific-papers].

States play a primary role in regulating most natural gas and oil development. EPA's authority is limited by statutory or regulatory exemptions under the Clean Water Act, Safe Drinking Water Act, the Comprehensive Environmental Response, Compensation and Liability Act, and the Resource Conservation and Recovery Act. Where EPA's exemptions exist, states may have authority to regulate unconventional oil and gas extraction activities under their own state laws.

EPA's draft assessment benefited from extensive stakeholder engagement conducted across the country with states, tribes, industry, non-governmental organizations, the scientific community and the public to ensure that the draft assessment reflects current practices in hydraulic fracturing and utilizes all data and information available to the agency.

The study will be finalized after review by the Science Advisory Board and public review and comment. The Federal Register Notice with information on the SAB review and how to comment on the draft assessment will be published on Friday June 5, 2015.

For a copy of the study, visit www.epa.gov/hfstudy.

To submit comments on the report, see www.epa.gov/sab.

From: Maloney, Kelsey
To: Maloney, Kelsey; Gibbons, Dayna; Frithsen, Jeff; Matthews, Lisa; Briskin, Jeanne; Smith, Kelley; Perry, Dale; Hubbard, Carolyn; Burke, Thomas; Bueno, Michael
CC: Allen, Laura; Purchia, Liz; Valentine, Julia; Hull, George; Milbourn, Cathy; Teichman, Kevin; Simunek, Diane; Ridley, Caroline
Sent: 6/2/2015 2:45:11 PM
Subject: HF Study Draft Assessment Public Webinar - 2

From: Maloney, Kelsey
To: Maloney, Kelsey; Briskin, Jeanne; Dean, Jill; Matthews, Lisa; Teichman, Kevin; Zambrana, Jose; Burden, Susan; Gibbons, Dayna; Hubbard, Carolyn; Perry, Dale; Frithsen, Jeff; Simunek, Diane
Sent: 3/24/2015 10:53:54 AM
Subject: FracFocus Public Webinar

A public webinar is scheduled on Monday, March 30, 2015 from 3:00pm-4:00pm where Jill will provide an overview of the FracFocus report. If you would like to join, I have reserved Hurd Hall as phone lines are limited.

From:	Frithsen, Jeff
To:	Burke, Thomas
Sent:	3/27/2015 1:36:11 PM
Subject:	Accepted: HF Drinking Water Chapter Comments: Executive Summary & chapters 6-10 (Discussion part 1)

From: Frithsen, Jeff
To: Burke, Thomas
Sent: 3/27/2015 1:35:15 PM
Subject: Accepted: HF Drinking Water Chapter Comments: 1,2,3, and 5

From: Frithsen, Jeff on behalf of Burke, Thomas
To: Briskin, Jeanne; Gibbons, Dayna; Matthews, Lisa; Teichman, Kevin; Zambrana, Jose
Sent: 3/16/2015 11:21:28 PM
Subject: FW: HF Paper Review with team

Sharing as FYI. The purpose of this meeting is for Tom to share comments with the authors of the Case Study Reports.

-----Original Appointment-----
From: Burke, Thomas
Sent: Tuesday, March 10, 2015 10:55 AM
To: Burke, Thomas; Matthews, Lisa; Teichman, Kevin; Frithsen, Jeff; Smith, Kelley; Sonich-Mullin, Cynthia; Smith, Kelly
Cc: Ludwig, Ralph; Wilkin, Rick; Beak, Doug; Lowrance, Richard
Subject: HF Paper Review with team
When: Tuesday, March 17, 2015 4:00 PM-5:30 PM (UTC-05:00) Eastern Time (US & Canada).
Where: **Ex. 6**

Would this time slot work for Tom and I to go over the following papers with the authors?

Kildeer, Wise, SWPA, RATON

From:	Frithsen, Jeff
To:	Fred Hauchman (hauchman.fred@epa.gov); Teichman, Kevin; Briskin, Jeanne; Kavlock, Robert
Sent:	3/7/2015 7:25:49 AM
Subject:	HF: Discussion of schedule for WFR#1 and Spills Report

Objective: What options for both staffing and process might we have so as to fully complete the WFR#1 and Spills report by May 14.

From:	Smith, Kelly
To:	Frithsen, Jeff
Sent:	4/23/2015 1:28:03 PM
Subject:	Accepted: HF: Retrospective Case Study Discussion

From:	Bond, Brian
To:	Bond, Brian; Ragland, Micah; Maddox, Donald; Marks, Teresa; Burke, Thomas; Gentry, Nathan; Hanley, Mary
CC:	Fritz, Matthew; Kadeli, Lek
Sent:	6/2/2015 10:59:56 AM
Subject:	Fracking Assessment Briefing

From:	Maddox, Donald on behalf of Bond, Brian
To:	Ragland, Micah; Maddox, Donald; Marks, Teresa; Burke, Thomas; Gentry, Nathan; Hanley, Mary
CC:	Fritz, Matthew; Kadeli, Lek
Sent:	6/2/2015 3:20:12 PM
Subject:	Fracking Assessment Briefing

From:	Gentry, Nathan on behalf of Burke, Thomas
To:	Rivera, Keylin; Porterfield, Teri; Kukla, Alison; Jones, Knolyn; Herckis, Arian; Fritz, Matthew; Burley, Veronica; Bluhm, Kate; Anderson, Denise
Sent:	5/7/2015 10:00:12 AM
Subject:	Accepted: Meeting RE: HF Assessment Roll-Out

From:	Piantanida, David
To:	Piantanida, David; Frithsen, Jeff; Gibbons, Dayna; Linkins, Samantha; Levine, Carolyn; Janifer, Pamela
Sent:	6/17/2015 4:24:51 PM
Subject:	Draft Assessment on the potential impacts to DW resources from HF Activities

Please reserve about 90 minutes for this hill briefing with DeGette staff and potentially staff from HEC, HSST and SEPW. If we have materials, please share with OCIR and we will decide when to share with the hill.

Thanks,

-David Piantanida

From:	Matthews, Lisa
To:	Matthews, Lisa; Frithsen, Jeff; Gibbons, Dayna
CC:	Sonich-Mullin, Cynthia; Zambrana, Jose; Bueno, Michael; Briskin, Jeanne; Kavlock, Robert; Orme-Zavaleta, Jennifer
Sent:	6/2/2015 9:29:37 AM
Subject:	Briefing for Technical Roundtable on Draft HFDWA

Draft Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources

Greetings Roundtable participants,

Today, the EPA released its *Draft Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources* for public comment and peer review, along with nine final peer-reviewed EPA technical reports completed as part of the study. The draft assessment provides the most complete compilation of scientific data to date on the potential impacts to drinking water resources from hydraulic fracturing activities. The draft assessment integrates a broad literature review, with results from EPA-led research projects and input from stakeholders through outreach efforts.

- Learn more about the Scientific Advisory Board's (SAB) peer review process for the draft assessment.

The EPA will be hosting a special webinar for our Technical Roundtable participants on **Wednesday, June 10, 2015 from 3:00 to 4:00 pm EDT** to provide a brief overview of the draft assessment, the key findings, and the review process.

To join the webinar:
https://epa.connectsolutions.com/epa-drafthfdwa/
Audio for this webinar is provided through your computer or device.

If you have trouble with the audio, you may call in to the conference line at **Ex. 6** *conference code:* **Ex. 6**

Thank you for your interest in the EPA's Study of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources.

Regards,
Lisa Matthews
US EPA Office of Research and Development
202-564-6669 office
Ex. 6
matthews.lisa@epa.gov

Here's the link:

Ex. 5

From: Maloney, Kelsey
Sent: Tuesday, June 02, 2015 12:34 PM
To: Johnson, Allen
Subject: 200 webinar room Tuesday 6/9, 2PM - HF Study

Â Hi Allen,

Can I reserve a 200 person webinar room on Tuesday, June 9th 2015 at 2PM from 2-4? Is it possible to put HFDWA EPA employee in the URL?

Â We will be using Daynaâ€™s call-in: Ex. 6 she will be a host as well).
Â

Thank you!
Â

Kelsey Maloney

Student Services Contractor

Science Communications

Office of Research and Development, US EPA

O: 202-564-4131

Maloney.kelsey@epa.gov

Â

From:	Kapuscinski, Jacques
To:	Kapuscinski, Jacques; carmeil_booker Ex. 4 ; Maloney, Kelsey; Hollandsworth, David; Dearie, Jessica
CC:	Gibbons, Dayna
Sent:	5/29/2015 10:39:14 AM
Subject:	HF Study follow up call
Attachments:	Ex. 5

From:	Frithsen, Jeff
To:	Frithsen, Jeff; Hanley, Mary; Gibbons, Dayna; Allen, Laura
CC:	Marks, Teresa
Sent:	5/28/2015 6:25:02 AM
Subject:	HFDWA: Last comments on revised executive summary
Attachments:	**Ex. 5**

I'm trying to schedule time early this morning to get last comments on the revised executive summary. I'm hoping this might work for folks.

The latest version of the executive summary was sent out late yesterday afternoon and is also attached below.

Jeff

From: Phillips, Anna
To: Phillips, Anna; Gibbons, Dayna; Briskin, Jeanne
Sent: 5/27/2015 10:07:43 AM
Subject: FW: HF Assessment Outreach

To talk about how to provide updates on the HF research and assessment to the international audiences.

Dayna,

Feel free to stop by my office for the call. Anna, we can also come to your desk to talk in person if you prefer.

Jeanne

-----Original Appointment-----
From: Phillips, Anna
Sent: Tuesday, May 26, 2015 6:54 PM
To: Phillips, Anna; Briskin, Jeanne
Subject: HF Assessment Outreach
When: Wednesday, May 27, 2015 12:30 PM-12:30 PM (UTC-05:00) Eastern Time (US & Canada).
Where:

We probably won't need the full 30 minutes but just in case…

From:	Breysse, Patrick N. (CDC/ONDIEH/NCEH)
To:	Breysse, Patrick N. (CDC/ONDIEH/NCEH); Frithsen, Jeff; Gibbons, Dayna; Briskin, Jeanne; Matthews, Lisa; Burke.Tom@epa.gov; Gentry, Nathan; Knutson, Donna (CDC/OCOO/OCFO)
CC:	Burke, Thomas
Sent:	5/21/2015 10:10:12 AM
Subject:	FW: New EPA Report about Fracking

FYI

-----Original Appointment-----
From: Breysse, Patrick N. (CDC/ONDIEH/NCEH) [mailto:pjb7@cdc.gov]
Sent: Wednesday, May 13, 2015 9:06 AM
To: Breysse, Patrick N. (CDC/ONDIEH/NCEH); Burke.Tom@epa.gov; Gentry, Nathan; Knutson, Donna (CDC/OCOO/OCFO)
Cc: Burke, Thomas
Subject: New EPA Report about Fracking
When: Tuesday, May 26, 2015 3:00 PM-4:00 PM (UTC-05:00) Eastern Time (US & Canada).
Where: Ex. 6

From: Allen, Laura
To: Allen, Laura; D'Andrea, Michael; Gray, David; Smith, Paula; Purchia, Liz; Gibbons, Dayna; Hubbard, Carolyn; Perry, Dale; Hanley, Mary; Valentine, Julia; Maloney, Kelsey; Matthews, Lisa
CC: Lee, Monica
Sent: 5/15/2015 11:53:15 AM
Subject: Chat about HF Case Studies messaging

Hey all- I had to shift the meeting time slightly so I hope it can still work for everyone.

Thanks again.

Hi all- as I mentioned earlier, we will go over the HF case studies messaging and get input from the PADs. I believe all of the ORD briefings for the states and RAs will be completed by this point, so hopefully this discussion can be informed by those.

We will circulate the final case studies messaging before this meeting, so we can discuss in detail.

Thanks!

Conference line:

Ex. 6

From: Maloney, Kelsey
To: Maloney, Kelsey; Kapuscinski, Jacques; Gibbons, Dayna; Booker, Carmeil; Hollandsworth, David; carmeil_booker Ex. 4
Sent: 5/11/2015 12:02:52 PM
Subject: Logistics for HF Draft Assessment posting

Hi all,

We'll be going over what support we'll need for posting the draft assessment and accompanying materials. Jacques can we use your call-in number?

Thanks,
Kelsey

From:	Burke, Thomas
To:	Burke, Thomas; Gibbons, Dayna; Smith, Kelley; Matthews, Lisa; Frithsen, Jeff; Briskin, Jeanne; Teichman, Kevin; Zambrana, Jose; Smith, Kelly
CC:	Kadeli, Lek; Kavlock, Robert; Blackburn, Elizabeth; Allen, Laura
Sent:	5/7/2015 12:49:14 PM
Subject:	HF DW Study State Presentation and Messaging discussion
Attachments:	Ex. 5

call-in: Ex. 6

From:	Smith, Kelley on behalf of Burke, Thomas
To:	Burke, Thomas; Frithsen, Jeff; Smith, Kelley; Matthews, Lisa; Gibbons, Dayna; Teichman, Kevin; Zambrana, Jose; Briskin, Jeanne; Smith, Kelly
CC:	Kadeli, Lek; Kavlock, Robert; Blackburn, Elizabeth
Sent:	5/7/2015 12:47:45 PM
Subject:	HF Retrospective State Presentation and Messaging discussion

call-in: Ex. 6

From: Matthews, Lisa
To: Matthews, Lisa; Garvin, Shawn; Early, William; Hedman, Susan; Kaplan, Robert; Burke, Thomas; Marks, Teresa; Frithsen, Jeff; Gibbons, Dayna; Smith, Kelley; Bueno, Michael; D'Andrea, Michael
CC: Perry, Dale; Allen, Laura; Purchia, Liz; Hubbard, Carolyn; Maloney, Kelsey
Sent: 4/30/2015 6:34:52 PM
Subject: Brief PA and OH state officials on Draft Assessment
Attachments: Ex. 5

Webinar: Ex. 6
Call-in Line: Ex. 6
Conference ID

POC -
Lisa Matthews Ex. 6
Michael Bueno 202-564-5051

From: Matthews, Lisa
To: Matthews, Lisa; McGrath, Shaun; Card, Joan; Marks, Teresa; Hanley, Mary; Perry, Dale; Burke, Thomas; Sonich-Mullin, Cynthia; Smith, Kelly; Gibbons, Dayna; Smith, Kelley; Zambrana, Jose
CC: Frithsen, Jeff; Varcoe, Betsy; Bueno, Michael; Kadeli, Lek; Beak, Doug; Lowrance, Richard; Jewett, David; Tom Burke; slmcgrath Ex. 4
Sent: 4/27/2015 12:03:59 PM
Subject: Brief ND state officials on Killdeer case study report
Attachments: Ex. 5

Webinar: Ex. 6
Call-in Line: Ex. 6
Conference ID:

Audio will be provided via a call-in line that our operator will manage to ensure only confirmed participants can connect.

Ex. 5

Expected participants:
Krista Carman, State of North Dakota-Office of the Governor (Washington office)
Andrea Travnicek, Senior Policy Advisor, State of North Dakota-Office of the Governor
David Glatt, Chief, Environmental Health Section, ND Department of Health
Lynn Helms, Director, Oil and Gas Division, ND Industrial Commission
Colleen Reinke, Director of Public Information, ND Department of Health

Thank you,
Lisa Matthews
US EPA Office of Research and Development
202-564-6669 office
Ex. 6

From:	Marks, Teresa
To:	Marks, Teresa; Matthews, Lisa; Frithsen, Jeff; Hanley, Mary; Maddox, Donald; Gibbons, Dayna
Sent:	4/24/2015 8:26:47 AM
Subject:	ORD HF Reports and Draft Assessment: Outreach Logistics

From:	Frithsen, Jeff
To:	Frithsen, Jeff; Sonich-Mullin, Cynthia; Smith, Kelly; Matthews, Lisa; Gibbons, Dayna; Zambrana, Jose
Sent:	4/23/2015 2:46:32 PM
Subject:	HF: Retrospective Case Study Discussion

Rescheduling due to conflicts any number of things!

Discussion of take home messages and coordination with states.

Apologies for stepping on any scheduled meetings.

From: Smith, Emily J.
To: Smith, Emily J.; Gibbons, Dayna; Maloney, Kelsey
Sent: 4/23/2015 11:14:01 AM
Subject: HF Source Apportionment Fact Sheet
Attachments: Ex. 5

Ex. 5 My calendar should be up to date. Thanks

202-564-7983
gibbons.dayna@epa.gov
Communications
Office of Research and Development
U.S. Environmental Protection Agency

From: Burke, Thomas
To: Burke, Thomas; Frithsen, Jeff; Briskin, Jeanne; Teichman, Kevin; Zambrana, Jose; Smith, Kelley; Kavlock, Robert; Vandenberg, John; Stanek, John; Yost, Erin; Matthews, Lisa; Gibbons, Dayna
Sent: 4/7/2015 11:26:19 AM
Subject: HF Discussion: DW Chapter 9 and Tox and QSAR reports

CT: Jeff Frithsen / Kelley Smith

Call: Ex. 6
Code

From: Burke, Thomas
To: Burke, Thomas; Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Zambrana, Jose; Teichman, Kevin; Briskin, Jeanne; Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Weaver, Jim; Stanek, John
CC: Kadeli, Lek; Kavlock, Robert; Jonathan.Koplos Ex. 4 Shari.Ring Ex. 4 MaryEllen.Tuccillo Ex. 4 Vandenberg, John; Walsh, Debra; Burgoon, Lyle; Yost, Erin; Fleming, Megan; Knightes, Chris
Sent: 3/27/2015 1:02:12 PM
Subject: HF Drinking Water Chapter Comments: Executive Summary & chapters 6 & 9 (Discussion part 1)

CT: Nathan Gentry

Teleconference: Ex. 6

Staff:

Notes: Discussion of comments for Chapters 6-10 and executive summary

From:	Burke, Thomas
To:	Burke, Thomas; Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Zambrana, Jose; Teichman, Kevin; Briskin, Jeanne; Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Weaver, Jim; Stanek, John
CC:	Kavlock, Robert; Kadeli, Lek; Jonathan.Koplos Ex. 4 Shari.Ring Ex. 4 MaryEllen.Tuccillo Ex. 4 Vandenberg, John; Walsh, Debra; Yost, Erin; Burgoon, Lyle; Fleming, Megan
Sent:	3/27/2015 1:02:57 PM
Subject:	HF Drinking Water Chapter Comments: Executive Summary & chapter 4 (Discussion part 2 - if needed)

CT: Nathan Gentry

Teleconference Ex. 6

Staff:

Notes: Discussion of comments for Chapters 6-10 and executive summary

From:	Burke, Thomas
To:	Burke, Thomas; Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Zambrana, Jose; Teichman, Kevin; Briskin, Jeanne; LeDuc, Stephen; Fleming, Megan; Ridley, Caroline
CC:	Kavlock, Robert; Kadeli, Lek
Sent:	3/27/2015 1:06:29 PM
Subject:	HF Drinking Water Chapter Comments: Chapter 4

CT: Nathan Gentry

Notes: Discussion of comments for Chapter 4

From:	Burke, Thomas
To:	Burke, Thomas; Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Yohannes, Lia; Knightes, Chris; Zambrana, Jose; Briskin, Jeanne; Teichman, Kevin
CC:	Kadeli, Lek; Kavlock, Robert; Jonathan.Koplos Ex. 4
Sent:	3/27/2015 12:57:34 PM
Subject:	HF Drinking Water Chapter Comments: 1,2,3, and 5

CT: Nathan Gentry

Teleconference: Details TBD

Staff:

Notes: Discussion of comments for Chapters 1-3 and 5.

From:	Burke, Thomas
To:	Burke, Thomas; Frithsen, Jeff; Gibbons, Dayna; Matthews, Lisa; Smith, Kelley; Dean, Jill; Teichman, Kevin; Briskin, Jeanne
Sent:	3/11/2015 1:27:46 PM
Subject:	HF Team Check in

Note new call-in number.

Check in time to discuss timing of FracFocus and any prep needed for WH meeting on Friday.

From:	Gibbons, Dayna
To:	Gibbons, Dayna
Sent:	3/10/2015 4:11:02 PM
Subject:	messages back to dale, messages for lisa m on overarching hf assessment, nga tps from ann hunter, comments to jeanne

---

From: Ridley, Caroline
To: Solomon, Sarah; Bates, William; Beak, Doug; Bergdale, Amy; Briskin, Jeanne; Bueno, Michael; Burden, Susan; Butler, Barbara; Clark, Christopher; Cluff, Maryam; Daiss, Rebecca; Dean, Jill; Deniz (Inci) Demirkanli; Fleming, Megan; Ford, Robert; Frithsen, Jeff; Gibbons, Dayna; Henderson, Michelle; Hillenbrand, Charles; Houck, Keith; Houk, Virginia; Impellitteri, Christopher; Jonathan.Koplos Ex. 4 Ken Klewicki Ex. 4 Knightes, Chris; Kraemer, Stephen; Landis, Matthew; LeDuc, Stephen; Ludwig, Ralph; MaryEllen.Tuccillo Ex. 4 Matthews, Lisa; Meza-Cuadra, Claudia; Mravik, Susan; Oberley, Gregory; Overbay, Michael; Richards, Matthew; Roberts, Cindy; Schumacher, Brian; Shari.Ring Ex. 4 Sharkey, Susan; Singer, Alison; Smith, Kelly; Souders, Steve; Stanek, John; Sullivan, Kate; Tinsley, Chuck; Todd, Jason; Watkins, Stephen; Weaver, Jim; Wilkin, Rick; Williams, Larke; Wiser, Nathan; Yohannes, Lia; Yost, Erin
CC: Tong-Argao, Sania; Williams, Joe; Auerbacher, Kevin; Bergman, Ronald; Biddle, Lisa; Carey, Kyle; Devir, Brian; Drees, Lauren; Elkins, Timothy; Ferguson, Holly; Foley, Gary; Fritz, Greg; Gillespie, Andrew; Ginsberg, Marilyn; Hanley, Adrian; Hauchman, Fred; Hyde, Tinka; Itkin, Cheryl; Jann, Stephen; Jewett, David; Johnson, Lora; Lewis, Paul; Little, Stephen; Matuszko, Jan; McDonald, Michael E.; Miller, Andy; Mottl, Nathan; Norris, Gary; Olszewski, John; ONeill, Sandra; Orme-Zavaleta, Jennifer; Pachnowski, Maya; Parikh, Pooja; Patterson, Craig; Piantanida, David; Pyne, Jaclyn; Robinson, Bonnie; Seltzer, Mark; Slimak, Michael; Sonich-Mullin, Cynthia; Soto, Vicki; Stewart, Andrew; Suarez, Luis; Teichman, Kevin; Trovato, Ramona; Vandegrift, Steve; Vandenberg, John; vanDrunick, Suzanne; Wilson, Scott; Zambrana, Jose; Zobrist, Marcus
Sent: 7/7/2015 4:36:06 PM
Subject: HFDWA monthly call

Ex. 5

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Ex. 6

Ex. 5

Please send agenda items by 4pm on Tuesday. An agenda will be sent by 9:30am the day of the meeting.
~~~~~~

From:	Frithsen, Jeff
To:	Hanley, Mary; Gibbons, Dayna; Allen, Laura
CC:	Marks, Teresa
Sent:	5/28/2015 8:00:29 AM
Subject:	HFDWA: Last comments on revised executive summary
Attachments:	Ex. 5

I'm trying to schedule time early this morning to get last comments on the revised executive summary. I'm hoping this might work for folks.

The latest version of the executive summary was sent out late yesterday afternoon and is also attached below.

Jeff

From: Briskin, Jeanne on behalf of Phillips, Anna
To: Gibbons, Dayna
Sent: 5/27/2015 10:07:40 AM
Subject: FW: HF Assessment Outreach

Ex. 5

Dayna,

Feel free to stop by my office for the call. Anna, we can also come to your desk to talk in person if you prefer.

Jeanne

-----Original Appointment-----
From: Phillips, Anna
Sent: Tuesday, May 26, 2015 6:54 PM
To: Phillips, Anna; Briskin, Jeanne
Subject: HF Assessment Outreach
When: Wednesday, May 27, 2015 12:30 PM-12:30 PM (UTC-05:00) Eastern Time (US & Canada).
Where:

We probably won't need the full 30 minutes but just in case...

From: Matthews, Lisa
To: McGrath, Shaun; Card, Joan; Marks, Teresa; Hanley, Mary; Perry, Dale; Burke, Thomas; Sonich-Mullin, Cynthia; Smith, Kelly; Gibbons, Dayna; Smith, Kelley; Zambrana, Jose
CC: Frithsen, Jeff; Varcoe, Betsy; Bueno, Michael; Kadeli, Lek; Beak, Doug; Lowrance, Richard; Jewett, David; Tom Burke; slmcgrath Ex. 4
Sent: 5/21/2015 6:01:38 PM
Subject: Brief ND state officials on Killdeer case study report
Attachments: Ex. 5

Webinar:
Call-in Line:
Conference ID: Ex. 6

Audio will be provided via a call-in line that our operator will manage to ensure only confirmed participants can connect.

Ex. 5
Ex. 5

Expected participants:
Krista Carman, State of North Dakota-Office of the Governor (Washington office)
Andrea Travnicek, Senior Policy Advisor, State of North Dakota-Office of the Governor
David Glatt, Chief, Environmental Health Section, ND Department of Health
Lynn Helms, Director, Oil and Gas Division, ND Industrial Commission
Colleen Reinke, Director of Public Information, ND Department of Health

Thank you,
Lisa Matthews
US EPA Office of Research and Development
202-564-6669 office
Ex. 6

From: Matthews, Lisa
To: Card, Joan; Smith, Kelly; Marks, Teresa; Burke, Thomas; Sonich-Mullin, Cynthia; Smith, Kelley; Gibbons, Dayna; McGrath, Shaun; Wilkin, Rick; Sullivan, Kate
CC: Zambrana, Jose; Varcoe, Betsy; Orme-Zavaleta, Jennifer; Bueno, Michael; Perry, Dale; Frithsen, Jeff; Hanley, Mary; Lowrance, Richard; Jewett, David; Deener, Kathleen; Gillespie, Andrew
Sent: 5/21/2015 11:04:10 AM
Subject: Brief CO state officials on Raton case study and water availability report
Attachments: Ex. 5

Ex. 6

Audio will be provided via a call-in line that our operator will manage to ensure only confirmed participants can connect.

Ex. 5
Ex. 5

Expected participants:

Dr. Larry Wolk (tentative), Executive Director and Chief Medical Officer, CO Department of Public Health and Environment
Martha Rudolph, Director of Environmental Programs, CO Department of Public Health and Environment
Andrew Ross, Senior Hydrogeologist, CO Department of Public Health and Environment

Matt Lepore, Director, CO Oil & Gas Conservation Commission
Robert Randall, Deputy Director, CO Department of Natural Resources
Kathleen Staks, Assistant Director for Energy, CO Department of Natural Resources
Kevin Rein, Deputy State Engineer, CO Department of Natural Resources

Thank you,
Lisa Matthews
US EPA Office of Research and Development
202-564-6669 office
Ex. 6

From:	Frithsen, Jeff
To:	Matthews, Lisa; Briskin, Jeanne; Teichman, Kevin; Zambrana, Jose; Gibbons, Dayna; Smith, Kelley
Sent:	5/18/2015 10:26:28 AM
Subject:	HF Core Team Huddle

Confirming that we should caucus today.

Ex. 5

From:	Gentry, Nathan on behalf of Burke, Thomas
To:	Hanley, Mary; Pahl, Dale; Allen, Laura; Purchia, Liz; Frithsen, Jeff; Smith, Kelley; Teichman, Kevin; Briskin, Jeanne; Gibbons, Dayna; Matthews, Lisa; Guido.DeHoratiis Ex. 6
CC:	Wiser, Nathan; Hauchman, Fred; Burden, Susan; Gant, Paula
Sent:	5/18/2015 9:10:10 AM
Subject:	EPA / DOE HF Call

CT: Kelley Smith, Smith.Kelley@epa.gov

Notes: Holding this time for a call between DOE and EPA. We are looking for a list of other invitees and confirmation that this time will work from DOE.

On May 13, 2015, at 5:13 PM, DeHoratiis, Guido Ex. 6 wrote:

Ex. 5

From: Matthews, Lisa
To: Garvin, Shawn; Early, William; Hedman, Susan; Kaplan, Robert; Burke, Thomas; Marks, Teresa; Frithsen, Jeff; Gibbons, Dayna; Smith, Kelley; Bueno, Michael; D'Andrea, Michael
CC: Perry, Dale; Allen, Laura; Purchia, Liz; Hubbard, Carolyn; Maloney, Kelsey
Sent: 5/15/2015 9:12:04 AM
Subject: Brief PA and OH state officials on Draft Assessment
Attachments: Ex. 5

Ex. 6

Ex. 6

POC -
Lisa Matthews Ex. 6
Michael Bueno 202-564-5051

Briefing for States on EPA's Draft Hydraulic Fracturing Drinking Water Assessment - Pennsylvania & Ohio

Ex. 6

Ex. 6

May 15, 2015
10:00am – 12:00 pm EDT

Purpose: *Briefing on the EPA's draft report, Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources. This assessment provides an evaluation of the potential impacts of hydraulic fracturing on drinking water resources and identifies key vulnerabilities.* ***The information presented at this meeting and discussed is embargoed until publicly released.***

Draft Agenda

Ex. 5

From: Matthews, Lisa
To: Garvin, Shawn; Early, William; D'Andrea, Michael; Marks, Teresa; Burke, Thomas; Hanley, Mary; Perry, Dale; Sonich-Mullin, Cynthia; Smith, Kelly; Smith, Kelley; Orme-Zavaleta, Jennifer; Sullivan, Kate; Gibbons, Dayna; Frithsen, Jeff; Zambrana, Jose
CC: Kadeli, Lek; Gillespie, Andrew; Allen, Laura; Purchia, Liz; Hubbard, Carolyn; Maloney, Kelsey; White, Terri-A; Thomas, Christopher
Sent: 5/15/2015 9:10:35 AM
Subject: Brief PA state officials on NEPA and SWPA case studies and water availability report
Attachments: Ex. 5

Ex. 6

Ex. 6

Shawn Garvin, Regional Administrator, US EPA Region 3
Bill Early, Deputy Regional Administrator, US EPA Region 3
Michael D'Andrea, PAD

POC -
Lisa Matthews Ex. 6
Michael Bueno 202-564-5051

Briefing for Pennsylvania State Agencies on
EPA's Retrospective Case Studies in NE and SW Pennsylvania and
Water Acquisition Report

Ex. 6

Ex. 6

May 15, 2015
1:30-2:30 pm EDT

Purpose: *Briefing on three EPA reports, Retrospective Case Study in Northeastern Pennsylvania, Retrospective Case Study in Southwestern Pennsylvania, and Case Study Analysis of the Impacts of Water Acquisition for Hydraulic Fracturing on Local Water Availability* (focus on Susquehanna River Basin)*.* ***The information presented at this meeting and discussed is embargoed until publicly released.***

Draft Agenda

Ex. 5

From: Ridley, Caroline
To: Bates, William; Beak, Doug; Bergdale, Amy; Briskin, Jeanne; Bueno, Michael; Burden, Susan; Burgoon, Lyle; Butler, Barbara; Clark, Christopher; Cluff, Maryam; Daiss, Rebecca; Dean, Jill; Deniz (Inci) Demirkanli; Fleming, Megan; Ford, Robert; Frithsen, Jeff; Gibbons, Dayna; Henderson, Michelle; Hillenbrand, Charles; Houck, Keith; Houk, Virginia; Impellitteri, Christopher; Jonathan.Koplos Ex. 4; Ken Klewicki Ex. 4; Knightes, Chris; Kraemer, Stephen; Landis, Matthew; LeDuc, Stephen; Ludwig, Ralph; MaryEllen.Tuccillo Ex. 4; Matthews, Lisa; Meza-Cuadra, Claudia; Mravik, Susan; Oberley, Gregory; Overbay, Michael; Richards, Matthew; Roberts, Cindy; Schumacher, Brian; Shari.Ring Ex. 4 Sharkey, Susan; Singer, Alison; Smith, Kelly; Souders, Steve; Stanek, John; Sullivan, Kate; Tinsley, Chuck; Todd, Jason; Watkins, Stephen; Weaver, Jim; Wilkin, Rick; Williams, Larke; Wiser, Nathan; Yohannes, Lia; Yost, Erin; Solomon, Sarah
CC: Auerbacher, Kevin; Bergman, Ronald; Biddle, Lisa; Carey, Kyle; Devir, Brian; Drees, Lauren; Elkins, Timothy; Ferguson, Holly; Foley, Gary; Fritz, Greg; Gillespie, Andrew; Ginsberg, Marilyn; Hanley, Adrian; Hauchman, Fred; Hyde, Tinka; Itkin, Cheryl; Jann, Stephen; Jewett, David; Johnson, Lora; Lewis, Paul; Little, Stephen; Matuszko, Jan; McDonald, Michael E.; Miller, Andy; Mottl, Nathan; Norris, Gary; Olszewski, John; ONeill, Sandra; Orme-Zavaleta, Jennifer; Pachnowski, Maya; Parikh, Pooja; Patterson, Craig; Piantanida, David; Pyne, Jaclyn; Robinson, Bonnie; Seltzer, Mark; Slimak, Michael; Sonich-Mullin, Cynthia; Soto, Vicki; Stewart, Andrew; Suarez, Luis; Teichman, Kevin; Trovato, Ramona; Vandegrift, Steve; Vandenberg, John; vanDrunick, Suzanne; Wilson, Scott; Zambrana, Jose; Zobrist, Marcus; Tong-Argao, Sania
Sent: 5/13/2015 9:59:36 AM
Subject: HFDWA monthly call

Today we will have a short update on the final EPA HF study products and the draft HF assessment that are scheduled to be release this month.

~~~~~~

Ex. 6

Ex. 5

Please send agenda items by 4pm on Tuesday. An agenda will be sent by 9:30am the day of the meeting.
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From: Smith, Kelley on behalf of Burke, Thomas
To: Gibbons, Dayna; Smith, Kelley; Matthews, Lisa; Frithsen, Jeff; Briskin, Jeanne; Teichman, Kevin; Zambrana, Jose; Smith, Kelly
CC: Kadeli, Lek; Kavlock, Robert; Blackburn, Elizabeth; Allen, Laura
Sent: 5/8/2015 12:32:45 PM
Subject: HF DW Study State Presentation and Messaging discussion
Attachments: **Ex. 5**

Ex. 6

From:	Gentry, Nathan on behalf of Burke, Thomas
To:	Gibbons, Dayna; Smith, Kelley; Matthews, Lisa; Frithsen, Jeff; Briskin, Jeanne; Teichman, Kevin; Zambrana, Jose; Smith, Kelly
CC:	Kadeli, Lek; Kavlock, Robert; Blackburn, Elizabeth
Sent:	5/7/2015 5:14:50 PM
Subject:	Canceled: HOLD: Possible last chance time for in person HF Retrospective or HF DW Study messaging or presentation Discussion time

Ex. 6

Note: Ideally we will not need this time, but we are placing a hold in the event that it is needed after the meeting earlier in the day (10:30 - 12:00 PM)

From:	Smith, Kelley on behalf of Burke, Thomas
To:	Frithsen, Jeff; Smith, Kelley; Matthews, Lisa; Gibbons, Dayna; Teichman, Kevin; Zambrana, Jose; Briskin, Jeanne; Smith, Kelly
CC:	Kadeli, Lek; Kavlock, Robert; Blackburn, Elizabeth
Sent:	5/7/2015 12:47:45 PM
Subject:	HF Retrospective State Presentation and Messaging discussion

Ex. 6

From: Frithsen, Jeff
To: Briskin, Jeanne; Gibbons, Dayna; Matthews, Lisa; Teichman, Kevin; Zambrana, Jose
Sent: 4/20/2015 9:17:40 AM
Subject: HF Core Team Huddle

Non-Responsive

Agenda items for today:

Ex. 5

Thanks.

From: Ridley, Caroline

To: Bates, William; Beak, Doug; Bergdale, Amy; Briskin, Jeanne; Bueno, Michael; Burden, Susan; Burgoon, Lyle; Butler, Barbara; Clark, Christopher; Cluff, Maryam; Daiss, Rebecca; Dean, Jill; Deniz (Inci) Demirkanli; Fleming, Megan; Ford, Robert; Frithsen, Jeff; Gibbons, Dayna; Henderson, Michelle; Hillenbrand, Charles; Houck, Keith; Houk, Virginia; Impellitteri, Christopher; Jonathan.Koplos Ex. 4 Ken Klewicki (Ken.Klewicki Ex. 4 ; Knightes, Chris; Kraemer, Stephen; Landis, Matthew; LeDuc, Stephen; Ludwig, Ralph; MaryEllen.Tuccillo Ex. 4 ; Matthews, Lisa; Meza-Cuadra, Claudia; Mravik, Susan; Oberley, Gregory; Overbay, Michael; Richards, Matthew; Roberts, Cindy; Schumacher, Brian; Shari.Ring Ex. 4 Sharkey, Susan; Singer, Alison; Smith, Kelly; Souders, Steve; Stanek, John; Sullivan, Kate; Tinsley, Chuck; Todd, Jason; Watkins, Stephen; Weaver, Jim; Wilkin, Rick; Williams, Larke; Wiser, Nathan; Yohannes, Lia; Yost, Erin

CC: Auerbacher, Kevin; Bergman, Ronald; Biddle, Lisa; Carey, Kyle; Devir, Brian; Drees, Lauren; Elkins, Timothy; Ferguson, Holly; Foley, Gary; Fritz, Greg; Gillespie, Andrew; Ginsberg, Marilyn; Hanley, Adrian; Hauchman, Fred; Hyde, Tinka; Itkin, Cheryl; Jann, Stephen; Jewett, David; Johnson, Lora; Lewis, Paul; Little, Stephen; Matuszko, Jan; McDonald, Michael E.; Miller, Andy; Mottl, Nathan; Norris, Gary; Olszewski, John; ONeill, Sandra; Orme-Zavaleta, Jennifer; Pachnowski, Maya; Parikh, Pooja; Patterson, Craig; Piantanida, David; Pyne, Jaclyn; Robinson, Bonnie; Seltzer, Mark; Slimak, Michael; Sonich-Mullin, Cynthia; Soto, Vicki; Stewart, Andrew; Suarez, Luis; Teichman, Kevin; Trovato, Ramona; Vandegrift, Steve; Vandenberg, John; vanDrunick, Suzanne; Wilson, Scott; Zambrana, Jose; Zobrist, Marcus; Tong-Argao, Sania

Sent: 4/7/2015 3:43:06 PM

Subject: HFDWA monthly call

Ex. 6

Ex. 5

Please send agenda items by 4pm on Tuesday. An agenda will be sent by 9:30am the day of the meeting.

From:	Gentry, Nathan on behalf of Burke, Thomas
To:	Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Zambrana, Jose; Teichman, Kevin; Briskin, Jeanne; LeDuc, Stephen; Fleming, Megan; Ridley, Caroline
CC:	Kavlock, Robert; Kadeli, Lek
Sent:	4/1/2015 2:42:02 PM
Subject:	HF Drinking Water Chapter Comments: Chapter 4

CT: Nathan Gentry

Notes: Discussion of comments for Chapter 4

From: Gibbons, Dayna
To: Frithsen, Jeff
Sent: 5/29/2015 11:10:56 AM
Subject: Accepted: HF: Assessment Outreach

From:	Gibbons, Dayna
To:	Allen, Laura
Sent:	5/18/2015 9:50:36 AM
Subject:	Accepted: Chat about HF Case Studies messaging

From: Gibbons, Dayna
To: Maloney, Kelsey
Sent: 5/12/2015 8:47:07 AM
Subject: Accepted: Logistics for HF Draft Assessment posting

From: Gibbons, Dayna
To: Burke, Thomas
Sent: 5/7/2015 4:34:33 PM
Subject: Accepted: HOLD: Possible last chance time for in person HF Retrospective or HF DW Study messaging or presentation Discussion time

From:	Gibbons, Dayna
To:	Allen, Laura; Hubbard, Carolyn; Hanley, Mary; Perry, Dale; Purchia, Liz; Maloney, Kelsey; Davis, Jay
CC:	Milbourn, Cathy; Matthews, Lisa; Loop, Travis; Ragland, Micah; Valentine, Julia; George Hull
Sent:	4/30/2015 9:42:18 AM
Subject:	Canceled: HF Communications Discussion

Folks—I really need to work on reviewing the communications materials for the retrospective case studies so I can share them w OPA before we send them over to the RAs for the meeting tomorrow.

Are people ok if we cancel today's meeting so I can get some of this done? I know Jay wanted to talk video today, but I really think this take precedence. Let me know if you disagree.

Thanks.

From: Gibbons, Dayna
To: Frithsen, Jeff
Sent: 4/23/2015 2:47:20 PM
Subject: Accepted: HF: Retrospective Case Study Discussion

From: Gibbons, Dayna
To: Frithsen, Jeff
Sent: 4/22/2015 4:50:28 PM
Subject: Declined: HF: Retrospective Case Study Discussion

Im out Friday morning. I'll catch up with you later in the day. Is there a meeting w Tom B tomorrow? Can you please send me the invite?

From:	Bond, Brian
To:	Bond, Brian; Ragland, Micah; Maddox, Donald; Marks, Teresa; Burke, Thomas; Gentry, Nathan; Hanley, Mary
CC:	Fritz, Matthew; Kadeli, Lek
Sent:	6/2/2015 10:59:54 AM
Subject:	Fracking Assessment Briefing

From: Frithsen, Jeff
To: Frithsen, Jeff; Hanley, Mary; Gibbons, Dayna; Allen, Laura
CC: Marks, Teresa
Sent: 5/28/2015 6:25:02 AM
Subject: HFDWA: Last comments on revised executive summary
Attachments: **Ex. 5**

I'm trying to schedule time early this morning to get last comments on the revised executive summary. I'm hoping this might work for folks.

The latest version of the executive summary was sent out late yesterday afternoon and is also attached below.

Jeff

From: Frithsen, Jeff
To: Frithsen, Jeff; Hanley, Mary; Perry, Dale; Kavlock, Robert
Sent: 4/29/2015 4:54:11 PM
Subject: HF: Feedback and all things considered

Comments on Well File Review Report

Comments on HFDWA Executive Summary

Note: Bob has a conflict and most likely will not be able to join us.

From:
To: Vandebrook, Lindsey (CONTR); Lenahan, Marni (CONTR); Melchert, Elena; Briskin, Jeanne; Williams, Larke; Ex. 4 Hakala, Alexandra (NETL); Ex. 4; 'Rose, Donna'; DeHoratiis, Guido; Teichman, Kevin; Ex. 4; Smith, Kelley; 'Ex. 4; Gant, Paula; Ex. 4'; Hanley, Mary; Martinez, Barbara; Ogunsola, Olayinka; Ex. 4
Sent:
Subject:
Attachments:

Ex. 5

Multi-Agency Collaboration on Unconventional Oil & Gas
Monday May 4th, 2015
4:00 PM - 5:00 PM
Call-in Number Ex. 6 (No Dial in Code Needed)

AGENDA

Ex. 5

Draft Notes Executive Committee Meeting
Monday April 27th, 2015
4:00 PM – 5:00 PM

Attendees: Kevin Teichman(EPA), Larke Williams (EPA), Barbara Martinez (EPA), Dave Russ (USGS), Vivian Nolan (USGS), Marni Lenahan (DOE), Lindsey VanDeBrook (DOE), Elena Melchert (DOE), Guido DeHoratiis (DOE)

Non-Responsive

Action: Dave will ask Lori if she received an invitation for drinking water and hydraulic fracturing report

Other

Non-Responsive

Non-Responsive

Multi-Agency Collaboration on Unconventional Oil & Gas
Monday May 4th, 2015
4:00 PM – 5:00 PM
Call-in Number Ex. 6 **(No Dial in Code Needed)**

AGENDA

Ex. 5

Carry-Over Action Items

Non-Responsive

Non-Responsive

From:	Marks, Teresa
To:	Marks, Teresa; Matthews, Lisa; Frithsen, Jeff; Hanley, Mary; Maddox, Donald; Gibbons, Dayna
Sent:	4/24/2015 8:25:53 AM
Subject:	ORD HF Reports and Draft Assessment: Outreach Logistics

From:	Frithsen, Jeff
To:	Frithsen, Jeff; Hanley, Mary; Perry, Dale; Kavlock, Robert; Teichman, Kevin; Orme-Zavaleta, Jennifer; Smith, Kelley
Sent:	4/7/2015 11:58:35 AM
Subject:	HF Report Discussion - Part 2

CT: Jeff Frithsen / Kelley Smith

Note: This is Part two, following on to the Wednesday 9:00 meeting. Tom is unable to participate in meeting part 2.

Focus of both meetings is on the HF Source Apportionment and Water Acquisition Reports.

From:	Burke, Thomas
To:	Burke, Thomas; Frithsen, Jeff; Smith, Kelley; Teichman, Kevin; Hanley, Mary; Perry, Dale; Kavlock, Robert
Sent:	4/7/2015 12:23:55 PM
Subject:	HF Report Discussion

CT: Jeff Frithsen / Kelley Smith

Ex. 6

Staff:
Mary Hanley, AO
Dale Perry, AO
Tom Burke, ORD
Bob Kavlock, ORD
Jeff Frithsen, ORD
Kevin Teichman, ORD
Kelley Smith, ORD

Note: Part one of two meetings to discuss Water Acquisition and Source Apportionment (Part 1 should focus on priority items). Jeff Frithsen will send a second invite for later in the day to cover the rest.

Please accept our apologies for the tough timing on this meeting as Tom has limited time this week and we are not able to shift his other meetings which are almost entirely Administrator priorities.

From: Jones, Jim
To: Jones, Jim; Cleland-Hamnett, Wendy; Morris, Jeff; Doa, Maria; Hofmann, Angela; Richmond, Jonah; Wills, Jennifer; Lobar, Bryan; Lewis, Paul; Mojica, Andrea; Flattery, Priscilla; Nielsen, Laura; Gonzalez, Yvonne V.; Smith, Peterj; Vendinello, Lynn; Grant, Brian; Rice, Cody; Widawsky, David; Mclean, Kevin; Mitchell, Stacey; Marks, Teresa; Hanley, Mary
CC: Auerbacher, Kevin
Sent: 4/6/2015 1:00:26 PM
Subject: Hydraulic Fracturing Briefing (Call in number Ex. 6
Attachments: Ex. 5

PURPOSE OF THIS MEETING
To brief Teresa Marks on the following action: Hydraulic Fracturing; Non-Responsive
Non-Responsive

From:	DCRoomARN3530CFTB/DC-Ariel-Rios-AO
To:	Hanley, Mary; Maddox, Donald
Sent:	4/24/2015 9:22:07 AM
Subject:	Accepted: ORD HF Reports and Draft Assessment: Outreach Logistics

Your request was accepted.

From:	Maddox, Donald
To:	Hanley, Mary; Maddox, Donald
Sent:	4/24/2015 9:22:06 AM
Subject:	Accepted: ORD HF Reports and Draft Assessment: Outreach Logistics

From: Frithsen, Jeff
To: Hanley, Mary; Maddox, Donald
Sent: 4/24/2015 8:28:18 AM
Subject: Accepted: ORD HF Reports and Draft Assessment: Outreach Logistics

From: Matthews, Lisa
To: Hanley, Mary; Maddox, Donald
Sent: 4/24/2015 8:28:01 AM
Subject: Accepted: ORD HF Reports and Draft Assessment: Outreach Logistics

From: Maddox, Donald on behalf of Bond, Brian
To: Hanley, Mary; Maddox, Donald
Sent: 6/2/2015 3:20:12 PM
Subject: Fracking Assessment Briefing

From:	Allen, Laura
To:	Hanley, Mary; Hubbard, Carolyn; Gibbons, Dayna; D'Andrea, Michael; Matthews, Lisa; Perry, Dale; Maloney, Kelsey; schafer, joan; White, Terri-A
CC:	Lee, Monica; Purchia, Liz
Sent:	5/28/2015 12:53:08 PM
Subject:	Canceled: Region 3 chat about HF assessment/case studies

Sorry folks, this time does not work for Dayna. I will work on rescheduling.

Hey all- this is to reconvene on the HF case studies messaging. Hopefully this time works for everyone. Thanks!

Phone

Ex. 6

From: Matthews, Lisa
To: Hanley, Mary; Maddox, Donald
Sent: 5/21/2015 6:01:38 PM
Subject: Brief ND state officials on Killdeer case study report
Attachments: Ex. 5

Ex. 6
Ex. 6

Audio will be provided via a call-in line that our operator will manage to ensure only confirmed participants can connect.

Ex. 5
Ex. 5

Expected participants:
Krista Carman, State of North Dakota-Office of the Governor (Washington office)
Andrea Travnicek, Senior Policy Advisor, State of North Dakota-Office of the Governor
David Glatt, Chief, Environmental Health Section, ND Department of Health
Lynn Helms, Director, Oil and Gas Division, ND Industrial Commission
Colleen Reinke, Director of Public Information, ND Department of Health

Thank you,
Lisa Matthews
US EPA Office of Research and Development
202-564-6669 office
Ex. 6

Briefing for North Dakota State Agencies on
EPA's Retrospective Case Study in Killdeer, ND

Ex. 6

Ex. 6

May 22, 2015
10:00-11:00 am CDT

Ex. 5

Draft Agenda

Ex. 5

From: Matthews, Lisa
To: McGrath, Shaun; Card, Joan; Marks, Teresa; Hanley, Mary; Perry, Dale; Burke, Thomas; Sonich-Mullin, Cynthia; Smith, Kelly; Gibbons, Dayna; Smith, Kelley; Zambrana, Jose
CC: Frithsen, Jeff; Varcoe, Betsy; Bueno, Michael; Kadeli, Lek; Beak, Doug; Lowrance, Richard; Jewett, David; Tom Burke; Ex. 4
Sent: 5/21/2015 6:01:38 PM
Subject: Brief ND state officials on Killdeer case study report
Attachments: Ex. 5

Ex. 6

Ex. 6

Audio will be provided via a call-in line that our operator will manage to ensure only confirmed participants can connect.

Ex. 5

Ex. 5

Expected participants:
Krista Carman, State of North Dakota-Office of the Governor (Washington office)
Andrea Travnicek, Senior Policy Advisor, State of North Dakota-Office of the Governor
David Glatt, Chief, Environmental Health Section, ND Department of Health
Lynn Helms, Director, Oil and Gas Division, ND Industrial Commission
Colleen Reinke, Director of Public Information, ND Department of Health

Thank you,
Lisa Matthews
US EPA Office of Research and Development
202-564-6669 office
Ex. 6

From: Matthews, Lisa
To: Hanley, Mary; Maddox, Donald
Sent: 5/21/2015 11:04:10 AM
Subject: Brief CO state officials on Raton case study and water availability report
Attachments: Ex. 5

Ex. 6
Ex. 6

Audio will be provided via a call-in line that our operator will manage to ensure only confirmed participants can connect.

Ex. 5

Expected participants:

Dr. Larry Wolk (tentative), Executive Director and Chief Medical Officer, CO Department of Public Health and Environment
Martha Rudolph, Director of Environmental Programs, CO Department of Public Health and Environment
Andrew Ross, Senior Hydrogeologist, CO Department of Public Health and Environment

Matt Lepore, Director, CO Oil & Gas Conservation Commission
Robert Randall, Deputy Director, CO Department of Natural Resources
Kathleen Staks, Assistant Director for Energy, CO Department of Natural Resources
Kevin Rein, Deputy State Engineer, CO Department of Natural Resources

Thank you,
Lisa Matthews
US EPA Office of Research and Development
202-564-6669 office
Ex. 6

Briefing for Colorado State Agencies on
EPA's Retrospective Case Study in the Raton Basin, CO and
Water Acquisition Report

Ex. 6

Ex. 6

May 21, 2015
2:30-3:30 pm MDT

Ex. 5

Draft Agenda

Ex. 5

From: Matthews, Lisa
To: Hanley, Mary; Maddox, Donald
Sent: 5/15/2015 9:12:04 AM
Subject: Brief PA and OH state officials on Draft Assessment
Attachments: Ex. 5

Ex. 6

POC -
Lisa Matthews Ex. 6
Michael Bueno 202-564-5051

Briefing for States on EPA's Draft Hydraulic Fracturing Drinking Water Assessment - Pennsylvania & Ohio

Ex. 6

May 15, 2015
10:00am – 12:00 pm EDT

Ex. 5

Draft Agenda

Ex. 5

DRAFT Notes Executive Committee Meeting
Monday May 4, 2015
4:00 pm – 5:00 pm

Attendees: Dave Russ (USGS), Vivian Nolan (USGS), Larke Williams (EPA), Barbara Martinez (EPA), Kevin Teichman (EPA), Guido DeHoratiis (DOE), Lindsey VanDeBrook (DOE)

Non-Responsive

EPA's Study of Hydraulic Fracturing and its Potential Impact on Drinking Water Resources Release

The EPA just finished briefing the Executive Office of the President on its HF Drinking Water Study, including its HF Drinking Water Assessment. DOI and DOE representatives attended the briefing. The nature of the questions asked mostly focused around being clear on messaging. The assessment and remaining technical reports are scheduled to go out in spring 2015; at the moment, the Agency is targeting the end of May for the public release of these documents.

Non-Responsive

Non-Responsive

Non-Responsive

From: Vandebrook, Lindsey (CONTR)
To: Lenahan, Marni (CONTR); Melchert, Elena; Briskin, Jeanne; Williams, Larke; 'jdbales@usgs.gov'; 'wlukas@usgs.gov'; Hakala, Alexandra (NETL); 'terzinda_vinson@ios.doi.gov'; 'vpnolan@usgs.gov'; 'rayboswell@netl.doe.gov'; 'Rose, Donna'; DeHoratiis, Guido; Teichman, Kevin; 'druss@usgs.gov'; Smith, Kelley; 'kzackschewski@usgs.gov'; Gant, Paula; 'lori_caramanian@ios.doi.gov.'; Hanley, Mary; Martinez, Barbara; Ogunsola, Olayinka; 'dhayba@usgs.gov'
Sent: 5/4/2015 10:58:27 AM
Subject: Multi-agency Collaboration (MAC) Steering/Executive Committee Meetings
Attachments: Ex. 5

Multi-Agency Collaboration on Unconventional Oil & Gas
Monday May 4th, 2015
4:00 PM – 5:00 PM
Call-in Number Ex. 6 (No Dial in Code Needed)

AGENDA

4:05 Approval of April 27th Meeting Notes
4:10 FY2015 Report to Congress Template
4:25 Update on Researcher/Policymaker Meeting
4:35 EPA's Study of Hydraulic Fracturing and Its Potential Impact on Drinking Water Resources release
4:45 Other

Carry-Over Action Items

Non-Responsive

Action: Dave will ask Lori if she received an invitation for drinking water and hydraulic fracturing report

Non-Responsive

Non-Responsive

Multi-Agency Collaboration on Unconventional Oil & Gas
Monday May 4th, 2015
4:00 PM – 5:00 PM
Call-in Number Ex. 6 (No Dial in Code Needed)

AGENDA

4:05 Approval of April 27th Meeting Notes

4:10 FY2015 Report to Congress Template

4:25 Update on Researcher/Policymaker Meeting

4:35 EPA's Study of Hydraulic Fracturing and Its Potential Impact on Drinking Water Resources release

4:45 Other

Carry-Over Action Items

Non-Responsive

Non-Responsive

From:	Burke, Thomas
To:	Burke, Thomas; Gibbons, Dayna; Smith, Kelley; Matthews, Lisa; Frithsen, Jeff; Briskin, Jeanne; Teichman, Kevin; Zambrana, Jose; Smith, Kelly
CC:	Kadeli, Lek; Kavlock, Robert; Blackburn, Elizabeth; Allen, Laura
Sent:	5/7/2015 12:49:14 PM
Subject:	HF DW Study State Presentation and Messaging discussion
Attachments:	**Ex. 5**

Ex. 6

From:	Burke, Thomas
To:	Burke, Thomas; Frithsen, Jeff; Smith, Kelley; Matthews, Lisa; Gibbons, Dayna; Teichman, Kevin; Zambrana, Jose; Briskin, Jeanne; Smith, Kelly
CC:	Kadeli, Lek; Kavlock, Robert; Blackburn, Elizabeth
Sent:	5/7/2015 12:47:48 PM
Subject:	HF Retrospective State Presentation and Messaging discussion

Ex. 6

From: Frithsen, Jeff
To: Frithsen, Jeff; Hanley, Mary; Perry, Dale; Kavlock, Robert
Sent: 4/29/2015 4:54:12 PM
Subject: HF: Feedback and all things considered

Non-Responsive

Comments on HFDWA Executive Summary

Note: Bob has a conflict and most likely will not be able to join us.

From:	Burke, Thomas
To:	Burke, Thomas; Frithsen, Jeff; Briskin, Jeanne; Teichman, Kevin; Zambrana, Jose; Smith, Kelley; Kavlock, Robert; Vandenberg, John; Stanek, John; Yost, Erin; Matthews, Lisa; Gibbons, Dayna
Sent:	4/7/2015 11:26:19 AM
Subject:	HF Discussion: DW Chapter 9 and Tox and QSAR reports

CT: Jeff Frithsen / Kelley Smith

Ex. 6

From: Burke, Thomas
To: Burke, Thomas; Frithsen, Jeff; Smith, Kelley; Teichman, Kevin; Hanley, Mary; Perry, Dale; Kavlock, Robert
Sent: 4/7/2015 11:24:34 AM
Subject: HF Report Discussion

CT: Jeff Frithsen / Kelley Smith

Ex. 6

Staff:
Mary Hanley, AO
Dale Perry, AO
Tom Burke, ORD
Bob Kavlock, ORD
Jeff Frithsen, ORD
Kevin Teichman, ORD
Kelley Smith, ORD

Note: Part one of two meetings to discuss Water Acquisition and Source Apportionment (Part 1 should focus on priority items). Jeff Frithsen will send a second invite for later in the day to cover the rest.

Please accept our apologies for the tough timing on this meeting as Tom has limited time this week and we are not able to shift his other meetings which are almost entirely Administrator priorities.

From:	Frithsen, Jeff
To:	Frithsen, Jeff; Hanley, Mary; Perry, Dale; Kavlock, Robert; Teichman, Kevin; Orme-Zavaleta, Jennifer; Smith, Kelley
Sent:	4/7/2015 12:04:27 PM
Subject:	HF Report Discussion - Part 2

CT: Jeff Frithsen / Kelley Smith

Note: This is Part two, following on to the Wednesday 9:00 meeting. Tom is unable to participate in meeting part 2.

Focus of both meetings is on the HF Source Apportionment and Water Acquisition Reports.

From: Burke, Thomas
To: Burke, Thomas; Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Zambrana, Jose; Teichman, Kevin; Briskin, Jeanne; Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Weaver, Jim; Stanek, John
CC: Kadeli, Lek; Kavlock, Robert; Jonathan.Koplos Ex. 4 Shari.Ring Ex. 4 MaryEllen.Tuccillo Ex. 4 Vandenberg, John; Walsh, Debra; Burgoon, Lyle; Yost, Erin; Fleming, Megan; Knightes, Chris
Sent: 3/27/2015 1:28:10 PM
Subject: HF Drinking Water Chapter Comments: Executive Summary & chapters 6 & 9 (Discussion part 1)

CT: Nathan Gentry

Teleconference: Ex. 6

Staff:

Notes: Discussion of comments for Chapters 6-10 and executive summary

From: Smith, Kelley on behalf of Burke, Thomas
To: Gibbons, Dayna; Smith, Kelley; Matthews, Lisa; Frithsen, Jeff; Briskin, Jeanne; Teichman, Kevin; Zambrana, Jose; Smith, Kelly
CC: Kadeli, Lek; Kavlock, Robert; Blackburn, Elizabeth; Allen, Laura
Sent: 5/8/2015 12:32:45 PM
Subject: HF DW Study State Presentation and Messaging discussion
Attachments: Ex. 5

Ex. 6

From:	Gentry, Nathan on behalf of Burke, Thomas
To:	Gibbons, Dayna; Smith, Kelley; Matthews, Lisa; Frithsen, Jeff; Briskin, Jeanne; Teichman, Kevin; Zambrana, Jose; Smith, Kelly
CC:	Kadeli, Lek; Kavlock, Robert; Blackburn, Elizabeth
Sent:	5/7/2015 5:14:50 PM
Subject:	Canceled: HOLD: Possible last chance time for in person HF Retrospective or HF DW Study messaging or presentation Discussion time

Ex. 6

Note: Ideally we will not need this time, but we are placing a hold in the event that it is needed after the meeting earlier in the day (10:30 - 12:00 PM)

From: Smith, Kelley on behalf of Burke, Thomas
To: Frithsen, Jeff; Smith, Kelley; Matthews, Lisa; Gibbons, Dayna; Teichman, Kevin; Zambrana, Jose; Briskin, Jeanne; Smith, Kelly
CC: Kadeli, Lek; Kavlock, Robert; Blackburn, Elizabeth
Sent: 5/7/2015 12:47:45 PM
Subject: HF Retrospective State Presentation and Messaging discussion

Ex. 6

From: Frithsen, Jeff
To: Hanley, Mary; Perry, Dale; Kavlock, Robert
Sent: 4/29/2015 4:54:08 PM
Subject: HF: Feedback and all things considered

Non-Responsive

Comments on HFDWA Executive Summary

Note: Bob has a conflict and most likely will not be able to join us.

From: Smith, Kelley on behalf of Burke, Thomas
To: Frithsen, Jeff; Smith, Kelley; Teichman, Kevin; Hanley, Mary; Perry, Dale; Kavlock, Robert
Sent: 4/7/2015 12:23:51 PM
Subject: HF Report Discussion

CT: Jeff Frithsen / Kelley Smith

Ex. 6

Staff:
Mary Hanley, AO
Dale Perry, AO
Tom Burke, ORD
Bob Kavlock, ORD
Jeff Frithsen, ORD
Kevin Teichman, ORD
Kelley Smith, ORD

Note: Part one of two meetings to discuss Water Acquisition and Source Apportionment (Part 1 should focus on priority items). Jeff Frithsen will send a second invite for later in the day to cover the rest.

Please accept our apologies for the tough timing on this meeting as Tom has limited time this week and we are not able to shift his other meetings which are almost entirely Administrator priorities.

From:	Frithsen, Jeff
To:	Hanley, Mary; Perry, Dale; Kavlock, Robert; Teichman, Kevin; Orme-Zavaleta, Jennifer; Smith, Kelley
Sent:	4/7/2015 12:04:24 PM
Subject:	HF Report Discussion - Part 2

CT: Jeff Frithsen / Kelley Smith

Note: This is Part two, following on to the Wednesday 9:00 meeting. Tom is unable to participate in meeting part 2.

Focus of both meetings is on the HF Source Apportionment and Water Acquisition Reports.

From: Smith, Kelley on behalf of Burke, Thomas
To: Frithsen, Jeff; Briskin, Jeanne; Teichman, Kevin; Zambrana, Jose; Smith, Kelley; Kavlock, Robert; Vandenberg, John; Stanek, John; Yost, Erin; Matthews, Lisa; Gibbons, Dayna
Sent: 4/7/2015 11:26:15 AM
Subject: HF Discussion: DW Chapter 9 and Tox and QSAR reports

CT: Jeff Frithsen / Kelley Smith

Ex. 6

From:	Gentry, Nathan on behalf of Burke, Thomas
To:	Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Zambrana, Jose; Teichman, Kevin; Briskin, Jeanne; LeDuc, Stephen; Fleming, Megan; Ridley, Caroline
CC:	Kavlock, Robert; Kadeli, Lek
Sent:	4/1/2015 2:42:02 PM
Subject:	HF Drinking Water Chapter Comments: Chapter 4

CT: Nathan Gentry

Notes: Discussion of comments for Chapter 4

From:	Kavlock, Robert on behalf of Burke, Thomas
To:	Robert Kavlock
CC:	Kavlock, Robert
Sent:	3/5/2015 11:07:17 AM
Subject:	Fwd: SSWR Program Briefing
Attachments:	**Ex. 5**

Begin forwarded message:

From: "Burke, Thomas" <Burke.Thomas@epa.gov>
To: "vanDrunick, Suzanne" <vanDrunick.Suzanne@epa.gov>, "Williams, Joe" <Williams.Joe@epa.gov>, "Mazur, Sarah" <Mazur.Sarah@epa.gov>, "Smith, Kelley" <Smith.Kelley@epa.gov>, "Blackburn, Elizabeth" <Blackburn.Elizabeth@epa.gov>, "Kadeli, Lek" <Kadeli.Lek@epa.gov>, "Corona, Elizabeth" <Corona.Elizabeth@epa.gov>
Cc: "Impellitteri, Christopher" <Impellitteri.Christopher@epa.gov>, "Rea, Anne" <Rea.Anne@epa.gov>, "Greene, Rick" <Greene.Rick@epa.gov>, "Pachnowski, Maya" <Pachnowski.Maya@epa.gov>, "Kavlock, Robert" <Kavlock.Robert@epa.gov>, "Gwinn, Maureen" <gwinn.maureen@epa.gov>
Subject: SSWR Program Briefing

Adding a call-in number so the meeting can proceed even if the gov't is closed tomorrow.

From: Burden, Susan
To: Burden, Susan; Ridley, Caroline; Wiser, Nathan; Shari.Ring Ex. 6
CC: LeDuc, Stephen; Jonathan.Koplos Ex. 6
Sent: 6/15/2015 10:47:40 AM
Subject: WFR2
Attachments: Ex. 5

Hi all,

See attached for some background documents for this afternoon's phone call.

~~~~~~

Hi all,

Let's meet to discuss the contents of WFR2. Nathan and I want to check in with the assessment team to make sure that we're providing useful information for Chapter 6.

Meeting materials will be sent out on Monday.

Thanks,

Susan
~~~~~~

From: LeDuc, Stephen
To: LeDuc, Stephen; ORD-NCEA
CC: Birchfield, Norman; Fritz, Jason; Cote, Ila; Owens, Beth; Ridley, Caroline; Carmichael, Brenda; James, Jennifer; Whalan, John; Johnson, Maureen; Ross, Alexandra; Phillips, Linda; Schappelle, Seema; Berner, Ted; Morefield, Philip; Rutigliano, Marian; Vandenberg, John; Euling, Susan; Johnson, Thomas; Dutton, Steven; Glenn, Barbara; Perovich, Gina; Saint, Chris; Yost, Erin; Julius, Susan; Itkin, Cheryl; Clark, Christopher; Todd, Jason; Bierwagen, Britta; Jones, Samantha; Suter, Glenn; Field, Malcolm; Wright, Michael; Coffman, Evan; Keshava, Channa; Troyer, Michael; Jinot, Jennifer; Greaver, Tara; Alexander, Laurie; Lorber, Matthew; Joca, Lauren; Cunningham, Taukecha; Woodall, George; Walsh, Debra; Jones, Ryan; Rieth, Susan; D'Amico, Louis; Gatchett, Annette; Walker, Lisa; Maxwell, April; Brown, James; Long, Tom; Gibbons, Catherine; Fox, John; Bland, Kathleen; Davis, Allen; Hagerthey, Scot; Starkey, Carol; Kraft, Andrew; Penalva-Arana, Carolina; Bussard, David; Moya, Jacqueline; Alcala, Cecilia; Flowers, Lynn; Chiu, Arthur; Lassiter, Meredith; Dishaw, Laura; Sonawane, Bob; Griffith, Michael; Solomon, Sarah; Rayhan, Sayeed (Rayhan.Sayeed@epa.gov); Bland, Naseera; DeSantis, Joe; Chan, Elizabeth
BCC: DCRoomPYN7100-River/ORD-NCEA-DC
Sent: 6/9/2015 3:41:24 PM
Subject: NCEA Presentation on Draft Hydraulic Fracturing Assessment
Attachments: Ex. 5

For those interested,

Caroline Ridley and I are providing an overview presentation on the Draft Hydraulic Fracturing Drinking Water Assessment. We released this assessment on June 4th and it covers the potential impacts of hydraulic fracturing activities on drinking water resources. This was a cross-ORD effort, with NCEA authors playing a prominent role. The presentation will last ca. 30-40 minutes with time for Q&A afterwards. Slides and call-in information are below.

Best,

Steve

Ex. 5

Ex. 6

From: LeDuc, Stephen
To: LeDuc, Stephen; Frithsen, Jeff; Ridley, Caroline
CC: Burden, Susan
Sent: 5/11/2015 10:07:27 AM
Subject: Ch 10 Synthesis
Attachments: Ex. 5

Hi all,

Ex. 5

I'm attaching an old version of Ch. 10---we are going update it with the new table 10.1 and ES language later today, so don't look at it for details. Just look at the end for big picture of the subjects we have in now, and what we might add.
Best, Steve

From: LeDuc, Stephen
To: LeDuc, Stephen; Frithsen, Jeff; Ridley, Caroline
BCC: DCRoomPYN7771-North/ORD-NCEA-DC
Sent: 5/7/2015 11:47:31 AM
Subject: ES/Ch10
Attachments: Ex. 5

Ex. 6 –I've pushed this start time back to 9:30am. Hopefully this still works for everyone.

Also, see latest ES attached.

From: Ridley, Caroline
To: Ridley, Caroline; Waltzer, Suzanne; Weitz, Melissa; Macpherson, Alex; Moore, Bruce; Burden, Susan
CC: LeDuc, Stephen; Wiser, Nathan; Briskin, Jeanne; Frithsen, Jeff
Sent: 4/28/2015 11:59:10 AM
Subject: OAR estimates of re-fracturing

Join us for a discussion of re-fracturing frequency, as estimated by OAR.
Additional perspective on fracturing in older wells will be provided by author(s) of ORD's Well File Review paper.

From: Fleming, Megan
To: Fleming, Megan; LeDuc, Stephen
Sent: 4/23/2015 4:09:36 PM
Subject: Ch. 4 Outstanding Comments
Attachments: Ex. 5

The chapter is attached Ex. 5

Ex. 5

I think we'll have no trouble getting through all the comments in 2 hours. Not many are time intensive.

Hi Steve - I can get the RRB 5th Floor Fish Bowl for 8:30 am Monday morning.

Does this work for you to walk thru some outstanding comments to Chapter 4?

Thanks,
Megan

From: Frithsen, Jeff
To: Frithsen, Jeff; Briskin, Jeanne; Gibbons, Dayna; Matthews, Lisa; Teichman, Kevin; Zambrana, Jose; Burden, Susan; LeDuc, Stephen; Ridley, Caroline; Hauchman, Fred; Piantanida, David; Houk, Virginia; Sonich-Mullin, Cynthia; Richards, Matthew; vanDrunick, Suzanne; Smith, Kelley; Smith, Kelly; Orme-Zavaleta, Jennifer; Vandenberg, John; Williams, Larke
Sent: 4/17/2015 2:58:01 PM
Subject: HF ORD Leadership Conference Call
Attachments: Canceled: HF ORD Leadership Conference Call; Canceled: HF ORD Leadership Conference Call; Canceled: HF ORD Leadership Conference Call

Note: New Teleconference Call Number: Ex. 6
Ex. 6

From:	Ridley, Caroline
To:	Ridley, Caroline; Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Jonathan.Koplos Ex. 4 Yohannes, Lia; Fleming, Megan; Knightes, Chris; Shari.Ring Ex. 4 ; Weaver, Jim; Cluff, Maryam; MaryEllen.Tuccillo Ex. 4 Stanek, John
Sent:	4/6/2015 3:46:00 PM
Subject:	HFDWA weekly chapter leads call
Attachments:	Ex. 5

Continuation of our weekly call.

Agenda to be sent week of.

From:
To: Ridley, Caroline; Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Jonathan.Koplos Ex. 4 ; Yohannes, Lia; Fleming, Megan; Knightes, Chris; Shari.Ring Ex. 4 ; Weaver, Jim; Cluff, Maryam; MaryEllen.Tuccillo Ex. 4 ; Stanek, John
Sent:
Subject:

Agenda
Chapter status updates

~~~~~~

Continuation of our weekly call.

Agenda to be sent week of.
~~~~~~

From:
To: Ridley, Caroline; Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Jonathan.Koplos Ex. 4 Yohannes, Lia; Fleming, Megan; Knightes, Chris; Shari.Ring Ex. 4 Weaver, Jim; Cluff, Maryam; MaryEllen.Tuccillo Ex. 4 Stanek, John
CC: Daiss, Rebecca
Sent:
Subject:

Please call in for a very brief touch-base- thanks!

~~~~~~
Continuation of our weekly call.

Agenda to be sent week of.
~~~~~~

From:
To: Ridley, Caroline; Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Jonathan.Koplos Ex. 4 Yohannes, Lia; Fleming, Megan; Knightes, Chris; Shari.Ring Ex. 4 Weaver, Jim; Cluff, Maryam; MaryEllen.Tuccillo Ex. 4 ; Stanek, John; Solomon, Sarah
Sent:
Subject:

Sorry for the schedule shuffle. Please make every effort to attend, or to at least send a chapter representative in your place if you absolutely cannot make it.

Agenda

Ex. 5

From:
To: Ridley, Caroline; Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Jonathan.Koplos Ex. 4 Yohannes, Lia; Fleming, Megan; Knightes, Chris; Shari.Ring Ex. 4 Weaver, Jim; Cliff, Maryam; MaryEllen.Tuccillo Ex. 4 Stanek, John; Solomon, Sarah
Sent:
Subject:

Thanks for being flexible with the timing of this meeting.

Agenda

Ex. 5

~~~~~~

Continuation of our weekly call.

Agenda to be sent week of.
~~~~~~

From:
To: Ridley, Caroline; Solomon, Sarah; Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Jonathan.Koplos Ex. 4 ; Yohannes, Lia; Fleming, Megan; Knightes, Chris; Shari.Ring Ex. 4 ; Weaver, Jim; Cluff, Maryam; MaryEllen.Tuccillo Ex. 4 ; Stanek, John
CC: Yost, Erin
Sent:
Subject:

Again- apologies for the calendar shuffle.
We will be talking progress towards assembling a complete draft of the HFDWA by Monday May 11.

~~~~~~

Continuation of our weekly call.

Agenda to be sent week of.
~~~~~~

From:
To: Ridley, Caroline; Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Jonathan.Koplos Ex. 4 Yohannes, Lia; Fleming, Megan; Knightes, Chris; Shari.Ring Ex. 4 Weaver, Jim; Cliff, Maryam; MaryEllen.Tuccillo Ex. 4 ; Stanek, John; Solomon, Sarah
Sent:
Subject:

Sorry for the shifting times. Trying to find a slot that works for most of us ....

Continuation of our weekly call.

Agenda to be sent week of.

From:
To: Ridley, Caroline; Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Jonathan.Koplos Ex. 4 Yohannes, Lia; Fleming, Megan; Knightes, Chris; Shari.Ring Ex. 4 Weaver, Jim; Cluff, Maryam; MaryEllen.Tuccillo Ex. 4 Stanek, John; Solomon, Sarah
Sent:
Subject:

We'll be touching base about final edits to the ES/chapter 10, plus the last steps running up to public release of our draft- exciting!

~~~~~~

Continuation of our weekly call.

Agenda to be sent week of.
~~~~~~

From: Ridley, Caroline
To: Ridley, Caroline; Burden, Susan; LeDuc, Stephen; Jonathan.Koplos Ex. 4 ; Yohannes, Lia; Fleming, Megan; Knightes, Chris; Shari.Ring Ex. 4 ; Weaver, Jim; Cluff, Maryam; MaryEllen.Tuccillo Ex. 4 ; Stanek, John; Frithsen, Jeff; Solomon, Sarah
Sent: 5/26/2015 12:28:52 PM
Subject: HFDWA weekly chapter leads call

Continuation of our weekly call.

Agenda to be sent week of.

From: Ridley, Caroline
To: Yohannes, Lia; Ridley, Caroline; Solomon, Sarah; Frithsen, Jeff; Jonathan.Koplos Ex. 4 Knightes, Chris; Burden, Susan; LeDuc, Stephen; Fleming, Megan; Shari.Ring Ex. 4 ; Weaver, Jim; Cluff, Maryam; MaryEllen.Tuccillo Ex. 4 ; Stanek, John
Sent: 5/26/2015 12:37:41 PM
Subject: HFDWA weekly chapter leads call

Agenda

Ex. 5

\`\`\`

Continuation of our weekly call.

Agenda to be sent week of.

From: Frithsen, Jeff
To: Frithsen, Jeff; Ridley, Caroline; Stanek, John; Yost, Erin; LeDuc, Stephen
Sent: 4/6/2015 12:19:26 PM
Subject: HF: Discussion of Chapter 9

Does this time work for folks?

From:	Burke, Thomas
To:	Burke, Thomas; Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Zambrana, Jose; Teichman, Kevin; Briskin, Jeanne; Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Weaver, Jim; Stanek, John
CC:	Kadeli, Lek; Kavlock, Robert; Jonathan.Koplos Ex. 4 ; Shari.Ring Ex. 4 ; MaryEllen.Tuccillo Ex. 4 ; Vandenberg, John; Walsh, Debra; Burgoon, Lyle; Yost, Erin; Fleming, Megan; Knightes, Chris
Sent:	3/27/2015 1:02:12 PM
Subject:	HF Drinking Water Chapter Comments: Executive Summary & chapters 6 & 9 (Discussion part 1)

CT: Nathan Gentry

Teleconference: Ex. 6

Staff:

Notes: Discussion of comments for Chapters 6-10 and executive summary

From:	Burke, Thomas
To:	Burke, Thomas; Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Zambrana, Jose; Teichman, Kevin; Briskin, Jeanne; Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Weaver, Jim; Stanek, John
CC:	Kavlock, Robert; Kadeli, Lek; Jonathan.Koplos Ex. 4; Shari.Ring Ex. 4 MaryEllen.Tuccillo Ex. 4 Vandenberg, John; Walsh, Debra; Yost, Erin; Burgoon, Lyle; Fleming, Megan
Sent:	3/27/2015 1:02:56 PM
Subject:	HF Drinking Water Chapter Comments: Executive Summary & chapter 4 (Discussion part 2 - if needed)

CT: Nathan Gentry

Teleconference: Ex. 6

Staff:

Notes: Discussion of comments for Chapters 6-10 and executive summary

From:	Burke, Thomas
To:	Burke, Thomas; Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Zambrana, Jose; Teichman, Kevin; Briskin, Jeanne; LeDuc, Stephen; Fleming, Megan; Ridley, Caroline
CC:	Kavlock, Robert; Kadeli, Lek
Sent:	3/27/2015 1:06:29 PM
Subject:	HF Drinking Water Chapter Comments: Chapter 4

CT: Nathan Gentry

Notes: Discussion of comments for Chapter 4

From:	Gentry, Nathan on behalf of Burke, Thomas
To:	Burke, Thomas; Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Yohannes, Lia; Knightes, Chris; Zambrana, Jose; Briskin, Jeanne; Teichman, Kevin
CC:	Kadeli, Lek; Kavlock, Robert; Jonathan.Koplos **Ex. 4**
Sent:	3/30/2015 9:06:29 AM
Subject:	HF Drinking Water Chapter Comments: 1,2,3, and 5

CT: Nathan Gentry

Teleconference: Details TBD

Staff:

Notes: Discussion of comments for Chapters 1-3 and 5.

From: Ridley, Caroline
To: Ridley, Caroline; Frithsen, Jeff; LeDuc, Stephen; Fleming, Megan; Weaver, Jim; MaryEllen.Tuccillo Ex. 4
Sent: 3/26/2015 3:20:56 PM
Subject: HF terminology: flowback, produced, wastewater

A final(?) discussion of the terms flowback, produced water, and hydraulic fracturing wastewater in the assessment.

From: Fleming, Megan
To: Fleming, Megan; Teichman, Kevin; LeDuc, Stephen; Frithsen, Jeff
Sent: 3/18/2015 3:14:10 PM
Subject: Water Acquisition - Options discussion
Attachments: Ex. 5

Ex. 5

The options paper is attached.

Ex. 6

From: Yohannes, Lia
To: Yohannes, Lia; Briskin, Jeanne; LeDuc, Stephen; Ridley, Caroline
Sent: 3/12/2015 9:57:16 AM
Subject: Ch3, 10 comments

Hi,

We would like to meet to discuss re: the following technical issues that affect at least Chapters 3, 9 and 10. Draft agenda and affected text below.

Draft agenda:

1. Discuss main issues of concern:

Ex. 5

2. Discuss options for moving forward

Affected text in chapter 3:

Ex. 5

Affected text in chapter 9, hazard evaluation:

Ex. 5

Affected text in chapter 10, synthesis:

Ex. 5

Thanks,
Lia

Liabeth Yohannes
Student Services Contractor
Office of Research and Development
U.S. Environmental Protection Agency
e: Yohannes.lia@epa.gov
p: 202.564.6755

From:	Ridley, Caroline
To:	Ridley, Caroline; Frithsen, Jeff; LeDuc, Stephen; Fleming, Megan; Weaver, Jim; MaryEllen.Tuccillo Ex. 4
Sent:	3/26/2015 3:20:56 PM
Subject:	HF terminology: flowback, produced, wastewater

A final(?) discussion of the terms flowback, produced water, and hydraulic fracturing wastewater in the assessment.

From:	Gentry, Nathan on behalf of Burke, Thomas
To:	Burke, Thomas; Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Yohannes, Lia; Knightes, Chris; Zambrana, Jose; Briskin, Jeanne; Teichman, Kevin
CC:	Kadeli, Lek; Kavlock, Robert; Jonathan.Koplos **Ex. 4**
Sent:	3/30/2015 9:06:29 AM
Subject:	HF Drinking Water Chapter Comments: 1,2,3, and 5

CT: Nathan Gentry

Teleconference: Details TBD

Staff:

Notes: Discussion of comments for Chapters 1-3 and 5.

From:	Microsoft Outlook on behalf of Buckley, Barbara
To:	LeDuc, Stephen
Sent:	6/16/2015 2:11:42 PM
Subject:	Meeting Forward Notification: NCEA Presentation on Draft Hydraulic Fracturing Assessment

Your meeting was forwarded

Buckley, Barbara has forwarded your meeting request to additional recipients.

Meeting

NCEA Presentation on Draft Hydraulic Fracturing Assessment

Meeting Time

Tuesday, June 16, 2015 1:00 PM-2:00 PM.

Recipients

Chan, Elizabeth

All times listed are in the following time zone: (UTC-05:00) Eastern Time (US & Canada)

Sent by Microsoft Exchange Server 2016

From: Bland, Naseera
To: LeDuc, Stephen
Sent: 6/16/2015 10:44:25 AM
Subject: Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Sonawane, Bob
To: LeDuc, Stephen
Sent: 6/15/2015 5:03:04 PM
Subject: Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Euling, Susan
To: LeDuc, Stephen
Sent: 6/15/2015 10:55:50 AM
Subject: Tentative: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From:	Dishaw, Laura
To:	LeDuc, Stephen
Sent:	6/15/2015 10:37:46 AM
Subject:	Declined: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Lassiter, Meredith
To: LeDuc, Stephen
Sent: 6/15/2015 10:29:33 AM
Subject: Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Chiu, Arthur
To: LeDuc, Stephen
Sent: 6/15/2015 7:11:40 AM
Subject: Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Flowers, Lynn
To: LeDuc, Stephen
Sent: 6/15/2015 6:15:10 AM
Subject: Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Bussard, David
To: LeDuc, Stephen
Sent: 6/12/2015 1:18:24 PM
Subject: Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Starkey, Carol
To: LeDuc, Stephen
Sent: 6/11/2015 10:32:23 AM
Subject: Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Hagerthey, Scot
To: LeDuc, Stephen
Sent: 6/11/2015 10:12:26 AM
Subject: Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Maxwell, April
To: LeDuc, Stephen
Sent: 6/10/2015 3:40:01 PM
Subject: Declined: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: D'Amico, Louis
To: LeDuc, Stephen
Sent: 6/10/2015 1:37:14 PM
Subject: Tentative: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Jones, Ryan
To: LeDuc, Stephen
Sent: 6/10/2015 12:56:40 PM
Subject: Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From:	Woodall, George
To:	LeDuc, Stephen
Sent:	6/10/2015 10:14:25 AM
Subject:	Declined: NCEA Presentation on Draft Hydraulic Fracturing Assessment

Steve,

Ex. 6 and will miss this meeting.

Best wishes,
George

From: Cunningham, Taukecha
To: LeDuc, Stephen
Sent: 6/10/2015 9:23:16 AM
Subject: Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Joca, Lauren
To: LeDuc, Stephen
Sent: 6/10/2015 9:17:52 AM
Subject: Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Phillips, Linda
To: LeDuc, Stephen
Sent: 6/10/2015 9:16:18 AM
Subject: Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Lorber, Matthew
To: LeDuc, Stephen
Sent: 6/10/2015 8:16:57 AM
Subject: Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Alexander, Laurie
To: LeDuc, Stephen
Sent: 6/10/2015 8:06:17 AM
Subject: Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From:	Bierwagen, Britta
To:	LeDuc, Stephen
Sent:	6/9/2015 5:57:10 PM
Subject:	Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From:	Clark, Christopher
To:	LeDuc, Stephen
Sent:	6/9/2015 5:04:02 PM
Subject:	Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Julius, Susan
To: LeDuc, Stephen
Sent: 6/9/2015 4:50:15 PM
Subject: Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Saint, Chris
To: LeDuc, Stephen
Sent: 6/9/2015 4:48:00 PM
Subject: Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Perovich, Gina
To: LeDuc, Stephen
Sent: 6/9/2015 4:44:33 PM
Subject: Tentative: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Glenn, Barbara
To: LeDuc, Stephen
Sent: 6/9/2015 4:42:33 PM
Subject: Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Euling, Susan
To: LeDuc, Stephen
Sent: 6/9/2015 4:08:17 PM
Subject: Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Vandenberg, John
To: LeDuc, Stephen
Sent: 6/9/2015 4:02:42 PM
Subject: Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From:	Rutigliano, Marian
To:	LeDuc, Stephen
Sent:	6/9/2015 3:59:11 PM
Subject:	Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From:	Morefield, Philip
To:	LeDuc, Stephen
Sent:	6/9/2015 3:54:45 PM
Subject:	Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From:	Berner, Ted
To:	LeDuc, Stephen
Sent:	6/9/2015 3:54:00 PM
Subject:	Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From:	Schappelle, Seema
To:	LeDuc, Stephen
Sent:	6/9/2015 3:52:38 PM
Subject:	Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From:	Phillips, Linda
To:	LeDuc, Stephen
Sent:	6/9/2015 3:51:40 PM
Subject:	Tentative: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From:	Ross, Alexandra
To:	LeDuc, Stephen
Sent:	6/9/2015 3:51:22 PM
Subject:	Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From:	Johnson, Maureen
To:	LeDuc, Stephen
Sent:	6/9/2015 3:51:22 PM
Subject:	Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Whalan, John
To: LeDuc, Stephen
Sent: 6/9/2015 3:50:45 PM
Subject: Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: James, Jennifer
To: LeDuc, Stephen
Sent: 6/9/2015 3:49:58 PM
Subject: Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Carmichael, Brenda
To: LeDuc, Stephen
Sent: 6/9/2015 3:49:08 PM
Subject: Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Ridley, Caroline
To: LeDuc, Stephen
Sent: 6/9/2015 3:48:40 PM
Subject: Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Owens, Beth
To: LeDuc, Stephen
Sent: 6/9/2015 3:45:42 PM
Subject: Tentative: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Cote, Ila
To: LeDuc, Stephen
Sent: 6/9/2015 3:43:45 PM
Subject: Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From:	Birchfield, Norman
To:	LeDuc, Stephen
Sent:	6/9/2015 3:42:50 PM
Subject:	Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Frithsen, Jeff
To: Vandenberg, John; Richards, Matthew; Burden, Susan; Sonich-Mullin, Cynthia; vanDrunick, Suzanne; Ridley, Caroline; Piantanida, David; LeDuc, Stephen; Gibbons, Dayna; Smith, Kelley; Teichman, Kevin; Houk, Virginia; Williams, Larke; Matthews, Lisa; Smith, Kelly; Briskin, Jeanne; Zambrana, Jose; Orme-Zavaleta, Jennifer; Hauchman, Fred
Sent: 5/8/2015 5:35:28 PM
Subject: Canceled: HF ORD Leadership Conference Call

I am cancelling the HF ORD Leadership call for Wednesday 5/13/2015. There are going to be a few folks on the road in Region 6 talking about the HF study/assessment.

Thanks.

Jeff

From: Frithsen, Jeff
To: Briskin, Jeanne; Gibbons, Dayna; Matthews, Lisa; Teichman, Kevin; Zambrana, Jose; Burden, Susan; LeDuc, Stephen; Ridley, Caroline; Hauchman, Fred; Piantanida, David; Houk, Virginia; Sonich-Mullin, Cynthia; Richards, Matthew; vanDrunick, Suzanne; Smith, Kelley; Smith, Kelly; Orme-Zavaleta, Jennifer; Vandenberg, John; Williams, Larke
Sent: 4/22/2015 9:00:59 AM
Subject: Canceled: HF ORD Leadership Conference Call

Team:

I am cancelling today's HF ORD Leadership Conference Call. No special reason, just much going on today and thought it better to free up everyone's calendar.

Ex. 5

Thanks again for everyone's focused efforts to get the HF study products and draft assessment over the finish line. We are making great progress. **Non-Responsive**

Jeff

From:	Gentry, Nathan on behalf of Burke, Thomas
To:	Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Zambrana, Jose; Teichman, Kevin; Briskin, Jeanne; LeDuc, Stephen; Fleming, Megan; Ridley, Caroline
CC:	Kavlock, Robert; Kadeli, Lek
Sent:	4/1/2015 2:42:02 PM
Subject:	HF Drinking Water Chapter Comments: Chapter 4

CT: Nathan Gentry

Notes: Discussion of comments for Chapter 4

From:	Smith, Kelley on behalf of Burke, Thomas
To:	Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Zambrana, Jose; Teichman, Kevin; Briskin, Jeanne; Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Weaver, Jim; Stanek, John
CC:	Kavlock, Robert; Kadeli, Lek; Jonathan.Koplos Ex. 4 Shari.Ring Ex. 4 MaryEllen.Tuccillo Ex. 4 Vandenberg, John; Walsh, Debra; Yost, Erin; Burgoon, Lyle; Fleming, Megan
Sent:	3/31/2015 10:51:18 AM
Subject:	HF Drinking Water Chapter Comments: Executive Summary & chapter 4 (Discussion part 2 - if needed)

CT: Nathan Gentry

Teleconference: **Ex. 6**

Staff:

Notes: Discussion of comments for Chapters 6-10 and executive summary

From:	Smith, Kelley on behalf of Burke, Thomas
To:	Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Zambrana, Jose; Teichman, Kevin; Briskin, Jeanne; Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Weaver, Jim; Stanek, John
CC:	Kadeli, Lek; Kavlock, Robert; Jonathan.Koplos Ex. 4 Shari.Ring Ex. 4 MaryEllen.Tuccillo Ex. 4 Vandenberg, John; Walsh, Debra; Burgoon, Lyle; Yost, Erin; Fleming, Megan; Knightes, Chris
Sent:	3/31/2015 10:51:10 AM
Subject:	HF Drinking Water Chapter Comments: Executive Summary & chapters 6 & 9 (Discussion part 1)

CT: Nathan Gentry

Teleconference: Ex. 6

Staff:

Notes: Discussion of comments for Chapters 6-10 and executive summary

From:	Gentry, Nathan on behalf of Burke, Thomas
To:	Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Yohannes, Lia; Knightes, Chris; Zambrana, Jose; Briskin, Jeanne; Teichman, Kevin
CC:	Kadeli, Lek; Kavlock, Robert; Jonathan.Koplos Ex. 4
Sent:	3/30/2015 9:06:29 AM
Subject:	HF Drinking Water Chapter Comments: 1,2,3, and 5

CT: Nathan Gentry

Teleconference: Details TBD

Staff:

Notes: Discussion of comments for Chapters 1-3 and 5.

From:	Yohannes, Lia
To:	Briskin, Jeanne; Burden, Susan; Daiss, Rebecca; Gibbons, Dayna; Matthews, Lisa; Roberts, Cindy; Sharkey, Susan; Tinsley, Chuck; Watkins, Stephen; Wiser, Nathan; Frithsen, Jeff; LeDuc, Stephen; Cluff, Maryam; Singer, Alison; Williams, Larke; Bueno, Michael; Fleming, Megan; Ridley, Caroline; Dean, Jill; Corona, Elizabeth; Hubbard, Carolyn
CC:	Maloney, Kelsey; Jonathan.Koplos Ex. 4 Shari.Ring Ex. 4 Knightes, Chris; MaryEllen.Tuccillo Ex. 4 Stanek, John; Weaver, Jim; Ex. 6
Sent:	3/10/2015 9:38:29 AM
Subject:	HF Team Meeting

Hi all,

Just wanted to let you know that Tom Burke is planning on stopping by during the meeting today. Also, we may end the meeting early since many will be attending the HFDWA Review Discussion with Bob Kavlock at 11am.

Thanks!

Ex. 6

Liabeth Yohannes
Student Services Contractor
Office of Research and Development
U.S. Environmental Protection Agency
e: Yohannes.lia@epa.gov
p: 202.564.6755

From: Ridley, Caroline
To: Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Jonathan.Koplos Ex. 4 Fleming, Megan; Knightes, Chris; Shari.Ring Ex. 4 Weaver, Jim; Cluff, Maryam; Impellitteri, Christopher; Stanek, John; MaryEllen.Tuccillo Ex. 4 Yohannes, Lia
CC: Deniz (Inci) Demirkanli
Sent: 3/4/2015 10:13:33 AM
Subject: HFDWA weekly chapter leads call

Agenda
Congrats! The draft is out!

Ex. 5

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Continuation of our weekly chapter leads call.

Ex. 6
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From: LeDuc, Stephen
To: Rayhan, Sayeed (Rayhan.Sayeed@epa.gov)
Sent: 6/16/2015 10:40:51 AM
Subject: FW: NCEA Presentation on Draft Hydraulic Fracturing Assessment
Attachments: Ex. 5

Sayeed,

Fyi...if you can help me set up. The slides are at the end. Best, Steve

-----Original Appointment-----
From: LeDuc, Stephen
Sent: Tuesday, June 09, 2015 3:41 PM
To: LeDuc, Stephen; ORD-NCEA
Cc: Birchfield, Norman; Fritz, Jason; Cote, Ila; Owens, Beth; Ridley, Caroline; Carmichael, Brenda; James, Jennifer; Whalan, John; Johnson, Maureen; Ross, Alexandra; Phillips, Linda; Schappelle, Seema; Berner, Ted; Morefield, Philip; Rutigliano, Marian; Vandenberg, John; Euling, Susan; Johnson, Thomas; Dutton, Steven; Glenn, Barbara; Perovich, Gina; Saint, Chris; Yost, Erin; Julius, Susan; Itkin, Cheryl; Clark, Christopher; Todd, Jason; Bierwagen, Britta; Jones, Samantha; Suter, Glenn; Field, Malcolm; Wright, Michael; Coffman, Evan; Keshava, Channa; Troyer, Michael; Jinot, Jennifer; Greaver, Tara; Alexander, Laurie; Lorber, Matthew; Joca, Lauren; Cunningham, Taukecha; Woodall, George; Walsh, Debra; Jones, Ryan; Rieth, Susan; D'Amico, Louis; Gatchett, Annette; Walker, Lisa; Maxwell, April; Brown, James; Long, Tom; Gibbons, Catherine; Fox, John; Bland, Kathleen; Davis, Allen; Hagerthey, Scot; Starkey, Carol; Kraft, Andrew; Penalva-Arana, Carolina; Bussard, David; Moya, Jacqueline; Alcala, Cecilia; Flowers, Lynn; Chiu, Arthur; Lassiter, Meredith; Dishaw, Laura; Sonawane, Bob; Griffith, Michael; Solomon, Sarah
Subject: NCEA Presentation on Draft Hydraulic Fracturing Assessment
When: Tuesday, June 16, 2015 1:00 PM-2:00 PM (UTC-05:00) Eastern Time (US & Canada).
Where: DCRoomPYN7100-River/ORD-NCEA-DC

For those interested,

Ex. 5

Best,

Steve

Ex. 5

Ex. 6

From:	LeDuc, Stephen
To:	Ridley, Caroline; Hagerthey, Scot
Sent:	6/16/2015 9:16:32 AM
Subject:	Monthly HF Update

Hi Scot, do you want an update on this? Best, Steve

Hi all,

I'm changing this to once a month and we can keep or cancel on an as needed basis. Best, Steve

Hi Caroline and Scot,

Trying to find a time slot to provide a verbal update on the HFDWA to Scot every 2 weeks. If this time doesn't work, please suggest another. Best, Steve

From: LeDuc, Stephen
To: Ridley, Caroline; Hagerthey, Scot
Sent: 6/2/2015 8:01:28 AM
Subject: Canceled: Biweekly HF Update

I'm canceling this Ex. 6

Stephen D. LeDuc, PhD
US Environmental Protection Agency
National Center for Environmental Assessment, Arlington, VA 22202
Office Phone: (703) 347-8962; Ex. 6

From: LeDuc, Stephen
To: Ridley, Caroline; Hagerthey, Scot
Sent: 4/7/2015 9:36:22 AM
Subject: Canceled: Biweekly HF Update

Hi Scot,

I need to cancel this meeting—we have some pressing deadlines. OK, with you? Best, Steve

Hi Caroline and Scot,

Trying to find a time slot to provide a verbal update on the HFDWA to Scot every 2 weeks. If this time doesn't work, please suggest another. Best, Steve

From: LeDuc, Stephen
To: Frithsen, Jeff
Sent: 4/6/2015 12:35:48 PM
Subject: Accepted: HF: Discussion of Chapter 9

From: LeDuc, Stephen
To: Burke, Thomas
Sent: 3/31/2015 10:50:53 AM
Subject: Accepted: HF Drinking Water Chapter Comments: Executive Summary & chapters 6-10 (Discussion part 1)

From:	LeDuc, Stephen
To:	Burke, Thomas
Sent:	3/31/2015 10:50:44 AM
Subject:	Accepted: HF Drinking Water Chapter Comments: Executive Summary & chapters 6-10 (Discussion part 2 - if needed)

From:	LeDuc, Stephen
To:	Burke, Thomas
Sent:	3/27/2015 2:57:10 PM
Subject:	Accepted: HF Drinking Water Chapter Comments: Executive Summary & chapters 6-10 (Discussion part 2 - if needed)

From: LeDuc, Stephen
To: Burke, Thomas
Sent: 3/27/2015 2:56:32 PM
Subject: Accepted: HF Drinking Water Chapter Comments: Chapter 4

From: LeDuc, Stephen
To: Burke, Thomas
Sent: 3/27/2015 1:42:46 PM
Subject: Accepted: HF Drinking Water Chapter Comments: Executive Summary & chapters 6-10 (Discussion part 1)

From: LeDuc, Stephen
To: Burke, Thomas
Sent: 3/27/2015 12:58:37 PM
Subject: Accepted: HF Drinking Water Chapter Comments: 1,2,3, and 5

From:	LeDuc, Stephen
To:	Ridley, Caroline; Hagerthey, Scot
Sent:	3/10/2015 9:50:17 AM
Subject:	Canceled: Biweekly HF Update

Hi Scot,

I'm canceling this meeting since we have to go downtown for a meeting with Bob Kavlock. Best, Steve

Stephen D. LeDuc, PhD
US Environmental Protection Agency
National Center for Environmental Assessment, Arlington, VA 22202
Office Phone: (703) 347-8962; Ex. 6

From: ORDVirtual RoomRequests
To: ORDVirtual RoomRequests; Gibbons, Dayna; Maloney, Kelsey; ORD Virtual Room 200-A/Virtual Seminar/ORD-Adobe Virtual Rooms
Sent: 6/3/2015 8:08:03 AM
Subject: Invitation: PSR200: Hydro Fracturing Drinking Water Assessment (dgibbons) (Jun 9 02:00 PM EDT)
Attachments: Ex. 5

Here's the link:

Ex. 6

____

From: Maloney, Kelsey
Sent: Tuesday, June 02, 2015 12:34 PM
To: Johnson, Allen
Subject: 200 webinar room Tuesday 6/9, 2PM - HF Study

Hi Allen,
Can I reserve a 200 person webinar room on Tuesday, June 9th 2015 at 2PM from 2-4? Is it possible to put HFDWA EPA employee in the URL?

Ex. 6

Thank you!

Kelsey Maloney

Student Services Contractor

Science Communications

Office of Research and Development, US EPA

O: 202-564-4131

Maloney.kelsey@epa.gov

From:	Maloney, Kelsey
To:	Maloney, Kelsey; Gibbons, Dayna; Frithsen, Jeff; Matthews, Lisa; Briskin, Jeanne; Smith, Kelley; Perry, Dale; Hubbard, Carolyn; Burke, Thomas; Bueno, Michael
CC:	Allen, Laura; Purchia, Liz; Valentine, Julia; Hull, George; Milbourn, Cathy; Teichman, Kevin; Simunek, Diane; Ridley, Caroline; Kadeli, Lek
Sent:	6/2/2015 2:45:05 PM
Subject:	HF Study Draft Assessment Public Webinar - 2

From:	Kapuscinski, Jacques
To:	Kapuscinski, Jacques; Ex. 6 Maloney, Kelsey; Hollandsworth, David; Dearie, Jessica
CC:	Gibbons, Dayna
Sent:	5/19/2015 3:55:03 PM
Subject:	HF Study follow up call
Attachments:	Ex. 5

From:	Allen, Laura
To:	Allen, Laura; D'Andrea, Michael; Gray, David; Smith, Paula; Purchia, Liz; Gibbons, Dayna; Hubbard, Carolyn; Perry, Dale; Hanley, Mary; Valentine, Julia; Maloney, Kelsey; Matthews, Lisa
CC:	Lee, Monica
Sent:	5/15/2015 11:53:14 AM
Subject:	Chat about HF Case Studies messaging

Hey all- I had to shift the meeting time slightly so I hope it can still work for everyone.

Thanks again.

Hi all- as I mentioned earlier, we will go over the HF case studies messaging and get input from the PADs. I believe all of the ORD briefings for the states and RAs will be completed by this point, so hopefully this discussion can be informed by those.

We will circulate the final case studies messaging before this meeting, so we can discuss in detail.

Thanks!

Conference line:

Ex. 6

From: Matthews, Lisa
To: Matthews, Lisa; Garvin, Shawn; Early, William; Hedman, Susan; Kaplan, Robert; Burke, Thomas; Marks, Teresa; Frithsen, Jeff; Gibbons, Dayna; Smith, Kelley; Bueno, Michael; D'Andrea, Michael
CC: Perry, Dale; Allen, Laura; Purchia, Liz; Hubbard, Carolyn; Maloney, Kelsey
Sent: 5/12/2015 10:21:34 AM
Subject: Brief PA and OH state officials on Draft Assessment
Attachments: Ex. 5

Ex. 6

Ex. 6

POC -
Lisa Matthews Ex. 6
Michael Bueno 202-564-5051

Briefing for States on EPA's Draft Hydraulic Fracturing Drinking Water Assessment - Pennsylvania & Ohio

Ex. 6

Ex. 6

May 15, 2015
10:00am – 12:00 pm EDT

Ex. 5

Draft Agenda

Ex. 5

From: Maloney, Kelsey
To: Maloney, Kelsey; Kapuscinski, Jacques; Gibbons, Dayna; Booker, Carmeil; Hollandsworth, David; carmeil_booker Ex. 4
Sent: 5/11/2015 12:02:47 PM
Subject: Logistics for HF Draft Assessment posting

Hi all,

We'll be going over what support we'll need for posting the draft assessment and accompanying materials. Jacques can we use your call-in number?

Thanks,
Kelsey

From: Kapuscinski, Jacques
To: Kapuscinski, Jacques; Johnson, Maureen; Maloney, Kelsey; Walter.Schwab Ex. 4 Itkin, Cheryl
Sent: 5/8/2015 2:11:40 PM
Subject: NCEA record in SI coordination with Draft assessment HF Study launch

Hi Maureen,
Kelsey Maloney is managing the HF Study Web site and is prepping materials for the launch of the site later in the month. Ex. 5

Ex. 5

Thank you,
Jacques

From: Smith, Emily J.
To: Smith, Emily J.; Gibbons, Dayna; Maloney, Kelsey
Sent: 4/23/2015 10:05:00 AM
Subject: HF Source Apportionment Fact Sheet
Attachments: Ex. 5

Ex. 5 My calendar should be up to date. Thanks

202-564-7983
gibbons.dayna@epa.gov
Communications
Office of Research and Development
U.S. Environmental Protection Agency

From:	Maloney, Kelsey
To:	ORDVirtual RoomRequests
Sent:	6/3/2015 8:52:58 AM
Subject:	Accepted: Invitation: PSR200: Hydro Fracturing Drinking Water Assessment (dgibbons) (Jun 9 02:00 PM EDT)

From:	Maloney, Kelsey
To:	Gibbons, Dayna; Frithsen, Jeff; Matthews, Lisa; Briskin, Jeanne; Smith, Kelley; Perry, Dale; Hubbard, Carolyn; Burke, Thomas; Bueno, Michael
CC:	Allen, Laura; Purchia, Liz; Valentine, Julia; Hull, George; Milbourn, Cathy; Teichman, Kevin; Simunek, Diane; Ridley, Caroline
Sent:	6/2/2015 2:45:08 PM
Subject:	HF Study Draft Assessment Public Webinar - 2

From:	Maloney, Kelsey
To:	Anley-Mills, Melissa
Sent:	5/21/2015 12:08:02 PM
Subject:	Canceled: HF draft assessment tweets

From: Maloney, Kelsey
To: Kapuscinski, Jacques; Gibbons, Dayna; Booker, Carmeil; Hollandsworth, David; carmeil_booker Ex. 4
Sent: 5/11/2015 12:02:49 PM
Subject: Logistics for HF Draft Assessment posting

Hi all,

We'll be going over what support we'll need for posting the draft assessment and accompanying materials. Jacques can we use your call-in number?

Thanks,
Kelsey

From:	Maloney, Kelsey
To:	Anley-Mills, Melissa
Sent:	5/11/2015 11:52:36 AM
Subject:	HF draft assessment tweets

From:	Maloney, Kelsey
To:	Kapuscinski, Jacques
Sent:	5/8/2015 2:27:28 PM
Subject:	Accepted: NCEA record in SI coordination with Draft assessment HF Study launch

---

From: Maloney, Kelsey
To: Simunek, Diane
Sent: 5/8/2015 1:45:58 PM
Subject: Hold for HF webinar

Change it date— Ex. 6

Hey—Any possibility you would be able to help out with logistics for the HF webinar (release of draft assessment)? Tentative date and times are Friday, May 22 at 10AM and 2PM, both 1-hour.

Thanks!!

From: Maloney, Kelsey
To: McGuinness, Moira
Sent: 5/6/2015 1:54:43 PM
Subject:

Hi Moira,

Does this date/time work to go over what we'll putting up on the web for the hf draft assessment?

Thanks,
Kelsey

From: Maloney, Kelsey
To: Simunek, Diane
Sent: 4/28/2015 10:13:09 AM
Subject: Hold for HF webinar

Hey—Any possibility you would be able to help out with logistics for the HF webinar (release of draft assessment)? Tentative date and times are Friday, May 22 at 10AM and 2PM, both 1-hour.

Thanks!!

From:	Bond, Brian
To:	Bond, Brian; Ragland, Micah; Maddox, Donald; Marks, Teresa; Burke, Thomas; Gentry, Nathan; Hanley, Mary
CC:	Fritz, Matthew; Kadeli, Lek
Sent:	6/2/2015 10:59:54 AM
Subject:	Fracking Assessment Briefing

From: Frithsen, Jeff
To: Frithsen, Jeff; Hanley, Mary; Gibbons, Dayna; Allen, Laura
CC: Marks, Teresa
Sent: 5/28/2015 7:20:10 AM
Subject: HFDWA: Last comments on revised executive summary
Attachments: **Ex. 5**

I'm trying to schedule time early this morning to get last comments on the revised executive summary. I'm hoping this might work for folks.

The latest version of the executive summary was sent out late yesterday afternoon and is also attached below.

Jeff

From:	Maddox, Donald on behalf of Marks, Teresa
To:	Marks, Teresa; Matthews, Lisa; Frithsen, Jeff; Hanley, Mary; Maddox Don (maddox.donald@epa.gov); Gibbons, Dayna
BCC:	DCRoomARN3530CFTB/DC-Ariel-Rios-AO
Sent:	4/24/2015 8:25:47 AM
Subject:	ORD HF Reports and Draft Assessment: Outreach Logistics

From: Frithsen, Jeff
To: Frithsen, Jeff; Marks, Teresa
Sent: 3/10/2015 4:29:03 PM
Subject: HF: Overview of ORD Study and Assessment

From: Maddox, Donald on behalf of Bond, Brian
To: Ragland, Micah; Maddox, Donald; Marks, Teresa; Burke, Thomas; Gentry, Nathan; Hanley, Mary
CC: Fritz, Matthew; Kadeli, Lek
Sent: 6/2/2015 3:20:12 PM
Subject: Fracking Assessment Briefing

From: Bond, Brian
To: Bond, Brian; Perry, Dale; Ragland, Micah; Maddox, Donald; Marks, Teresa; Burke, Thomas; Gentry, Nathan; Hanley, Mary
CC: Fritz, Matthew; Kadeli, Lek; Smith, Kelley; Frithsen, Jeff; Matthews, Lisa; Gibbons, Dayna
Sent: 6/3/2015 9:06:28 AM
Subject: Fracking Assessment Briefing

From: Maloney, Kelsey
To: Maloney, Kelsey; Gibbons, Dayna; Frithsen, Jeff; Matthews, Lisa; Briskin, Jeanne; Smith, Kelley; Perry, Dale; Hubbard, Carolyn; Burke, Thomas; Bueno, Michael
CC: Allen, Laura; Purchia, Liz; Valentine, Julia; Hull, George; Milbourn, Cathy; Teichman, Kevin; Simunek, Diane; Ridley, Caroline
Sent: 6/2/2015 2:45:09 PM
Subject: HF Study Draft Assessment Public Webinar - 2

From: Allen, Laura
To: Allen, Laura; D'Andrea, Michael; Gray, David; Smith, Paula; Purchia, Liz; Gibbons, Dayna; Hubbard, Carolyn; Perry, Dale; Hanley, Mary; Valentine, Julia; Maloney, Kelsey; Matthews, Lisa
CC: Lee, Monica
Sent: 5/15/2015 11:53:15 AM
Subject: Chat about HF Case Studies messaging

Hey all- I had to shift the meeting time slightly so I hope it can still work for everyone.

Thanks again.

Hi all- as I mentioned earlier, we will go over the HF case studies messaging and get input from the PADs. I believe all of the ORD briefings for the states and RAs will be completed by this point, so hopefully this discussion can be informed by those.

We will circulate the final case studies messaging before this meeting, so we can discuss in detail.

Thanks!

Ex. 6

From: Frithsen, Jeff
To: Frithsen, Jeff; Hanley, Mary; Perry, Dale; Kavlock, Robert
Sent: 4/29/2015 4:54:10 PM
Subject: HF: Feedback and all things considered

Comments on Well File Review Report

Comments on HFDWA Executive Summary

Note: Bob has a conflict and most likely will not be able to join us.

From: Matthews, Lisa
To: Matthews, Lisa; Card, Joan; Smith, Kelly; Marks, Teresa; Burke, Thomas; Sonich-Mullin, Cynthia; Smith, Kelley; Gibbons, Dayna; McGrath, Shaun; Wilkin, Rick; Sullivan, Kate
CC: Zambrana, Jose; Varcoe, Betsy; Orme-Zavaleta, Jennifer; Bueno, Michael; Perry, Dale; Frithsen, Jeff; Hanley, Mary; Lowrance, Richard; Jewett, David; Deener, Kathleen; Gillespie, Andrew
Sent: 4/27/2015 12:30:35 PM
Subject: Brief CO state officials on Raton case study and water availability report
Attachments: Ex. 5

Ex. 6

Audio will be provided via a call-in line that our operator will manage to ensure only confirmed participants can connect.

Ex. 5

Expected participants:

Dr. Larry Wolk (tentative), Executive Director and Chief Medical Officer, CO Department of Public Health and Environment
Martha Rudolph, Director of Environmental Programs, CO Department of Public Health and Environment
Andrew Ross, Senior Hydrogeologist, CO Department of Public Health and Environment

Matt Lepore, Director, CO Oil & Gas Conservation Commission
Robert Randall, Deputy Director, CO Department of Natural Resources
Kathleen Staks, Assistant Director for Energy, CO Department of Natural Resources
Kevin Rein, Deputy State Engineer, CO Department of Natural Resources

Thank you,
Lisa Matthews
US EPA Office of Research and Development
202-564-6669 office
Ex. 6

From: Matthews, Lisa
To: Matthews, Lisa; McGrath, Shaun; Card, Joan; Marks, Teresa; Hanley, Mary; Perry, Dale; Burke, Thomas; Sonich-Mullin, Cynthia; Smith, Kelly; Gibbons, Dayna; Smith, Kelley; Zambrana, Jose
CC: Frithsen, Jeff; Varcoe, Betsy; Bueno, Michael; Kadeli, Lek; Beak, Doug; Lowrance, Richard; Jewett, David; Tom Burke; Ex. 6
Sent: 4/27/2015 12:03:59 PM
Subject: Brief ND state officials on Killdeer case study report
Attachments: Ex. 5

Ex. 6

Audio will be provided via a call-in line that our operator will manage to ensure only confirmed participants can connect.

Ex. 5

Expected participants:
Krista Carman, State of North Dakota-Office of the Governor (Washington office)
Andrea Travnicek, Senior Policy Advisor, State of North Dakota-Office of the Governor
David Glatt, Chief, Environmental Health Section, ND Department of Health
Lynn Helms, Director, Oil and Gas Division, ND Industrial Commission
Colleen Reinke, Director of Public Information, ND Department of Health

Thank you,
Lisa Matthews
US EPA Office of Research and Development
202-564-6669 office
Ex. 6

From:	Frithsen, Jeff
To:	Frithsen, Jeff; Hanley, Mary; Perry, Dale; Kavlock, Robert; Teichman, Kevin; Orme-Zavaleta, Jennifer; Smith, Kelley
Sent:	4/7/2015 11:58:35 AM
Subject:	HF Report Discussion - Part 2

CT: Jeff Frithsen / Kelley Smith

Note: This is Part two, following on to the Wednesday 9:00 meeting. Tom is unable to participate in meeting part 2.

Focus of both meetings is on the HF Source Apportionment and Water Acquisition Reports.

From:	Burke, Thomas
To:	Burke, Thomas; Frithsen, Jeff; Smith, Kelley; Teichman, Kevin; Hanley, Mary; Perry, Dale; Kavlock, Robert
Sent:	4/7/2015 11:22:23 AM
Subject:	HF Report Discussion

CT: Jeff Frithsen / Kelley Smith

Ex. 6

Staff:
Mary Hanley, AO
Dale Perry, AO
Tom Burke, ORD
Bob Kavlock, ORD
Jeff Frithsen, ORD
Kevin Teichman, ORD
Kelley Smith, ORD

Note: Part one of two meetings to discuss Water Acquisition and Source Apportionment (Part 1 should focus on priority items). Jeff Frithsen will send a second invite for later in the day to cover the rest.

Please accept our apologies for the tough timing on this meeting as Tom has limited time this week and we are not able to shift his other meetings which are almost entirely Administrator priorities.

From: Perry, Dale
To: Allen, Laura
Sent: 5/27/2015 10:56:42 AM
Subject: Declined: Region 3 chat about HF assessment/case studies

From: Perry, Dale
To: Frithsen, Jeff
Sent: 4/7/2015 12:04:55 PM
Subject: Accepted: HF Report Discussion - Part 2

From: Perry, Dale
To: Frithsen, Jeff
Sent: 4/7/2015 12:00:51 PM
Subject: Accepted: HF Report Discussion - Part 2

From: Allen, Laura
To: Allen, Laura; Smith, Roxanne; Hull, George; Slotkin, Ron; Hart, Daniel; Orquina, Jessica; Davis, Jay; Purchia, Liz; Abrams, Dan; Valentine, Julia; Milbourn, Cathy; Daguillard, Robert; Kowalski, Kennedy; Hanley, Mary; Perry, Dale; Lee, Monica
Sent: 6/1/2015 5:52:34 PM
Subject: HF Public Affairs meeting

Hey folks- we will use this time to review the tick tock for the HF assessment. We'll go over the info below in more detail. Thanks, and see you then!

Ex. 5

Ex. 5

From:	Allen, Laura
To:	Allen, Laura; Hanley, Mary; Hubbard, Carolyn; Gibbons, Dayna; D'Andrea, Michael; Matthews, Lisa; Perry, Dale; Maloney, Kelsey; schafer, joan; White, Terri-A
CC:	Lee, Monica; Purchia, Liz
Sent:	5/27/2015 9:33:54 AM
Subject:	Canceled: Region 3 chat about HF assessment/case studies

Sorry folks, this time does not work for Dayna. I will work on rescheduling.

Hey all- this is to reconvene on the HF case studies messaging. Hopefully this time works for everyone. Thanks!

Ex. 6

From:	Maloney, Kelsey
To:	Gibbons, Dayna; Frithsen, Jeff; Matthews, Lisa; Briskin, Jeanne; Smith, Kelley; Perry, Dale; Hubbard, Carolyn; Burke, Thomas; Bueno, Michael
CC:	Allen, Laura; Purchia, Liz; Valentine, Julia; Hull, George; Milbourn, Cathy; Teichman, Kevin; Simunek, Diane; Ridley, Caroline
Sent:	6/2/2015 2:45:07 PM
Subject:	HF Study Draft Assessment Public Webinar - 2

From: Allen, Laura
To: Smith, Roxanne; Hull, George; Slotkin, Ron; Hart, Daniel; Orquina, Jessica; Davis, Jay; Purchia, Liz; Abrams, Dan; Valentine, Julia; Milbourn, Cathy; Daguillard, Robert; Kowalski, Kennedy; Hanley, Mary; Perry, Dale; Lee, Monica
Sent: 6/1/2015 5:52:31 PM
Subject: HF Public Affairs meeting

Hey folks- we will use this time to review the tick tock for the HF assessment. We'll go over the info below in more detail. Thanks, and see you then!

Ex. 5

Ex. 5

From:	Gibbons, Dayna
To:	Allen, Laura; Hubbard, Carolyn; Hanley, Mary; Perry, Dale; Purchia, Liz; Maloney, Kelsey; Davis, Jay
CC:	Milbourn, Cathy; Matthews, Lisa; Loop, Travis; Ragland, Micah; Valentine, Julia; Hull, George
Sent:	4/30/2015 9:42:17 AM
Subject:	Canceled: HF Communications Discussion

Ex. 5

Are people ok if we cancel today's meeting so I can get some of this done? I know Jay wanted to talk video today, but I really think this take precedence. Let me know if you disagree.

Thanks.

From:	Maloney, Kelsey
To:	Maloney, Kelsey; Gibbons, Dayna; Frithsen, Jeff; Matthews, Lisa; Briskin, Jeanne; Smith, Kelley; Perry, Dale; Hubbard, Carolyn; Burke, Thomas; Bueno, Michael
CC:	Allen, Laura; Purchia, Liz; Valentine, Julia; Hull, George; Milbourn, Cathy; Teichman, Kevin; Simunek, Diane; Ridley, Caroline
Sent:	6/2/2015 2:45:09 PM
Subject:	HF Study Draft Assessment Public Webinar - 2

From: Meacham, Connie
To: Meacham, Connie; Ridley, Caroline; Frithsen, Jeff; Walsh, Debra
Sent: 5/27/2015 10:19:31 AM
Subject: Preparing the SAB Copy of HF Report & Appendices - - & Plan of action for next week's Final Report & Final Appendices

Hi Caroline & Jeff - (Debra - you are optional on this call) -

Ex. 5

From: Ridley, Caroline
To: Ridley, Caroline; Waltzer, Suzanne; Weitz, Melissa; Macpherson, Alex; Moore, Bruce; Burden, Susan
CC: LeDuc, Stephen; Wiser, Nathan; Briskin, Jeanne; Frithsen, Jeff; Jonathan Koplos
Sent: 4/28/2015 11:59:06 AM
Subject: OAR estimates of re-fracturing

Join us for a discussion of re-fracturing frequency, as estimated by OAR.
Additional perspective on fracturing in older wells will be provided by author(s) of ORD's Well File Review paper.

From: Ridley, Caroline
To: Jonathan Koplos
Sent: 4/27/2015 4:13:13 PM
Subject: HFDWA chapter 2

Ex. 5

From: Ridley, Caroline
To: Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Jonathan Koplos; Yohannes, Lia; Fleming, Megan; Knightes, Chris; Shari Ring; Weaver, Jim; Cluff, Maryam; Mary Ellen Tuccillo; Stanek, John; Solomon, Sarah
Sent: 4/6/2015 3:45:55 PM
Subject: HFDWA weekly chapter leads call
Attachments: Ex. 5

Continuation of our weekly call.

Agenda to be sent week of.

From:
To: Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Jonathan Koplos; Yohannes, Lia; Fleming, Megan; Knightes, Chris; Shari Ring; Weaver, Jim; Cluff, Maryam; Mary Ellen Tuccillo; Stanek, John
Sent:
Subject:

Agenda
Chapter status updates

~~~~~~

Continuation of our weekly call.

Agenda to be sent week of.
~~~~~~

From:
To: Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Jonathan Koplos; Yohannes, Lia; Fleming, Megan; Knightes, Chris; Shari Ring; Weaver, Jim; Cluff, Maryam; Mary Ellen Tuccillo; Stanek, John; Solomon, Sarah
CC: Daiss, Rebecca
Sent:
Subject:

Please call in for a very brief touch-base- thanks!

~~~~~~
Continuation of our weekly call.

Agenda to be sent week of.
~~~~~~

From:
To: Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Jonathan Koplos; Yohannes, Lia; Fleming, Megan; Knightes, Chris; Shari Ring; Weaver, Jim; Cluff, Maryam; Mary Ellen Tuccillo; Stanek, John; Solomon, Sarah
CC: Yost, Erin
Sent:
Subject:

Sorry for the schedule shuffle. Please make every effort to attend, or to at least send a chapter representative in your place if you absolutely cannot make it.

Agenda

Ex. 5

From:
To: Ridley, Caroline; Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Jonathan Koplos; Yohannes, Lia; Fleming, Megan; Knightes, Chris; Shari Ring; Weaver, Jim; Cluff, Maryam; Mary Ellen Tuccillo; Stanek, John; Solomon, Sarah
Sent:
Subject:

Thanks for being flexible with the timing of this meeting.

Agenda

Ex. 5

~~~~~~

Continuation of our weekly call.

Agenda to be sent week of.
~~~~~~

From:
To: Solomon, Sarah; Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Jonathan Koplos; Yohannes, Lia; Fleming, Megan; Knightes, Chris; Shari Ring; Weaver, Jim; Cluff, Maryam; Mary Ellen Tuccillo; Stanek, John
CC: Yost, Erin
Sent:
Subject:

Again- apologies for the calendar shuffle.
We will be talking progress towards assembling a complete draft of the HFDWA by Monday May 11.

~~~~~~
Continuation of our weekly call.

Agenda to be sent week of.
~~~~~~

From:
To: Ridley, Caroline; Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Jonathan Koplos; Yohannes, Lia; Fleming, Megan; Knightes, Chris; Shari Ring; Weaver, Jim; Cluff, Maryam; Mary Ellen Tuccillo; Stanek, John; Solomon, Sarah
Sent:
Subject:

Sorry for the shifting times. Trying to find a slot that works for most of us ....

Continuation of our weekly call.

Agenda to be sent week of.

From:
To: Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Jonathan Koplos; Yohannes, Lia; Fleming, Megan; Knightes, Chris; Shari Ring; Weaver, Jim; Cluff, Maryam; Mary Ellen Tuccillo; Stanek, John; Solomon, Sarah
Sent:
Subject:

We'll be touching base about final edits to the ES/chapter 10, plus the last steps running up to public release of our draft- exciting!

~~~~~~

Continuation of our weekly call.

Agenda to be sent week of.
~~~~~~

From:
To: Frithsen, Jeff; Solomon, Sarah; Burden, Susan; LeDuc, Stephen; Jonathan Koplos; Yohannes, Lia; Fleming, Megan; Knightes, Chris; Shari Ring; Weaver, Jim; Cluff, Maryam; Mary Ellen Tuccillo; Stanek, John
Sent:
Subject:

From:
To: Solomon, Sarah; Frithsen, Jeff; Jonathan Koplos; Knightes, Chris; Burden, Susan; LeDuc, Stephen; Fleming, Megan; Shari Ring; Weaver, Jim; Cluff, Maryam; Mary Ellen Tuccillo; Stanek, John; Yohannes, Lia
CC: Yost, Erin
Sent:
Subject:

Agenda

Ex. 5

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Continuation of our weekly call.

Agenda to be sent week of.
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From:	Frithsen, Jeff
To:	Frithsen, Jeff; Ridley, Caroline; Stanek, John; Yost, Erin; LeDuc, Stephen
Sent:	4/6/2015 12:19:27 PM
Subject:	HF: Discussion of Chapter 9

Does this time work for folks?

From: Burke, Thomas
To: Burke, Thomas; Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Zambrana, Jose; Teichman, Kevin; Briskin, Jeanne; Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Weaver, Jim; Stanek, John
CC: Kavlock, Robert; Kadeli, Lek; Jonathan.Koplos Ex. 4 ; Shari.Ring Ex. 4 MaryEllen.Tuccillo Ex. 4 Vandenberg, John; Walsh, Debra; Yost, Erin; Burgoon, Lyle; Fleming, Megan
Sent: 3/27/2015 1:02:57 PM
Subject: HF Drinking Water Chapter Comments: Executive Summary & chapter 4 (Discussion part 2 - if needed)

CT: Nathan Gentry

Teleconference: Ex. 6

Staff:

Notes: Discussion of comments for Chapters 6-10 and executive summary

From:	Burke, Thomas
To:	Burke, Thomas; Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Zambrana, Jose; Teichman, Kevin; Briskin, Jeanne; LeDuc, Stephen; Fleming, Megan; Ridley, Caroline
CC:	Kavlock, Robert; Kadeli, Lek
Sent:	3/27/2015 1:06:28 PM
Subject:	HF Drinking Water Chapter Comments: Chapter 4

CT: Nathan Gentry

Notes: Discussion of comments for Chapter 4

From:	Burke, Thomas
To:	Burke, Thomas; Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Yohannes, Lia; Knightes, Chris; Zambrana, Jose; Briskin, Jeanne; Teichman, Kevin
CC:	Kadeli, Lek; Kavlock, Robert; Jonathan.Koplos Ex. 4
Sent:	3/27/2015 12:57:34 PM
Subject:	HF Drinking Water Chapter Comments: 1,2,3, and 5

CT: Nathan Gentry

Teleconference: Details TBD

Staff:

Notes: Discussion of comments for Chapters 1-3 and 5.

From: Yohannes, Lia
To: Yohannes, Lia; Briskin, Jeanne; LeDuc, Stephen; Ridley, Caroline
Sent: 3/13/2015 4:28:16 PM
Subject: Ch3, 10 comments

Hi,

We would like to meet to discuss re: the following technical issues that affect at least Chapters 3, 9 and 10. Draft agenda and affected text below.

Ex. 5

Thanks,
Lia

Liabeth Yohannes
Student Services Contractor
Office of Research and Development
U.S. Environmental Protection Agency
e: Yohannes.lia@epa.gov
p: 202.564.6755

From:	Ridley, Caroline
To:	Jonathan Koplos; Mary Ellen Tuccillo; Frithsen, Jeff
Sent:	3/3/2015 12:56:24 PM
Subject:	HFDWA wastewater work
Attachments:	**Ex. 5**

We will be talking about the follow-on list of tasks in the attached document, as well as Keven Teichman's review comments.

From: Jonathan Koplos
To: Ridley, Caroline
Sent: 5/29/2015 1:56:52 PM
Subject: Accepted: HF chemicals eDB and 508 work

1pm Tues works fine.

Ex. 5

Congrats on getting the draft together!

Ex. 5

CADMUS

Follow us on social media:

From:	Gentry, Nathan on behalf of Burke, Thomas
To:	Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Zambrana, Jose; Teichman, Kevin; Briskin, Jeanne; LeDuc, Stephen; Fleming, Megan; Ridley, Caroline
CC:	Kavlock, Robert; Kadeli, Lek
Sent:	4/1/2015 2:42:02 PM
Subject:	HF Drinking Water Chapter Comments: Chapter 4

CT: Nathan Gentry

Notes: Discussion of comments for Chapter 4

From: Smith, Kelley on behalf of Burke, Thomas
To: Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Zambrana, Jose; Teichman, Kevin; Briskin, Jeanne; Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Weaver, Jim; Stanek, John
CC: Kavlock, Robert; Kadeli, Lek; Jonathan.Koplos Ex. 4 ; Shari.Ring Ex. 4 MaryEllen.Tuccillo Ex. 4 Vandenberg, John; Walsh, Debra; Yost, Erin; Burgoon, Lyle; Fleming, Megan
Sent: 3/31/2015 10:51:18 AM
Subject: HF Drinking Water Chapter Comments: Executive Summary & chapter 4 (Discussion part 2 - if needed)

CT: Nathan Gentry

Teleconference: Ex. 6

Staff:

Notes: Discussion of comments for Chapters 6-10 and executive summary

From:	Smith, Kelley on behalf of Burke, Thomas
To:	Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Zambrana, Jose; Teichman, Kevin; Briskin, Jeanne; Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Weaver, Jim; Stanek, John
CC:	Kadeli, Lek; Kavlock, Robert; Jonathan.Koplos Ex. 4; Shari.Ring Ex. 4 MaryEllen.Tuccillo Ex. 4 Vandenberg, John; Walsh, Debra; Burgoon, Lyle; Yost, Erin; Fleming, Megan; Knightes, Chris
Sent:	3/31/2015 10:51:10 AM
Subject:	HF Drinking Water Chapter Comments: Executive Summary & chapters 6 & 9 (Discussion part 1)

CT: Nathan Gentry

Teleconference: Ex. 6

Staff:

Notes: Discussion of comments for Chapters 6-10 and executive summary

From: Gentry, Nathan on behalf of Burke, Thomas
To: Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Yohannes, Lia; Knightes, Chris; Zambrana, Jose; Briskin, Jeanne; Teichman, Kevin
CC: Kadeli, Lek; Kavlock, Robert; Jonathan.Koplos Ex. 4
Sent: 3/30/2015 9:06:29 AM
Subject: HF Drinking Water Chapter Comments: 1,2,3, and 5

CT: Nathan Gentry

Teleconference: Details TBD

Staff:

Notes: Discussion of comments for Chapters 1-3 and 5.

From: Yohannes, Lia
To: Briskin, Jeanne; LeDuc, Stephen; Ridley, Caroline
Sent: 3/16/2015 9:06:33 AM
Subject: Ch3, 10 comments

Hi,

Ex. 5

Thanks,
Lia

Liabeth Yohannes
Student Services Contractor
Office of Research and Development
U.S. Environmental Protection Agency
e: Yohannes.lia@epa.gov
p: 202.564.6755

From:	Ridley, Caroline
To:	Solomon, Sarah; Bates, William; Beak, Doug; Bergdale, Amy; Briskin, Jeanne; Bueno, Michael; Burden, Susan; Butler, Barbara; Clark, Christopher; Cluff, Maryam; Daiss, Rebecca; Dean, Jill; Deniz (Inci) Demirkanli; Fleming, Megan; Ford, Robert; Frithsen, Jeff; Gibbons, Dayna; Henderson, Michelle; Hillenbrand, Charles; Houck, Keith; Houk, Virginia; Impellitteri, Christopher; Jonathan Koplos; Ken Klewicki Ex. 4; Knightes, Chris; Kraemer, Stephen; Landis, Matthew; LeDuc, Stephen; Ludwig, Ralph; Mary Ellen Tuccillo; Matthews, Lisa; Meza-Cuadra, Claudia; Mravik, Susan; Oberley, Gregory; Overbay, Michael; Richards, Matthew; Roberts, Cindy; Schumacher, Brian; Shari Ring; Sharkey, Susan; Singer, Alison; Smith, Kelly; Souders, Steve; Stanek, John; Sullivan, Kate; Tinsley, Chuck; Todd, Jason; Watkins, Stephen; Weaver, Jim; Wilkin, Rick; Williams, Larke; Wiser, Nathan; Yohannes, Lia; Yost, Erin
CC:	Tong-Argao, Sania; Williams, Joe; Auerbacher, Kevin; Bergman, Ronald; Biddle, Lisa; Carey, Kyle; Devir, Brian; Drees, Lauren; Elkins, Timothy; Ferguson, Holly; Foley, Gary; Fritz, Greg; Gillespie, Andrew; Ginsberg, Marilyn; Hanley, Adrian; Hauchman, Fred; Hyde, Tinka; Itkin, Cheryl; Jann, Stephen; Jewett, David; Johnson, Lora; Lewis, Paul; Little, Stephen; Matuszko, Jan; McDonald, Michael E.; Miller, Andy; Mottl, Nathan; Norris, Gary; Olszewski, John; ONeill, Sandra; Orme-Zavaleta, Jennifer; Pachnowski, Maya; Parikh, Pooja; Patterson, Craig; Piantanida, David; Pyne, Jaclyn; Robinson, Bonnie; Seltzer, Mark; Slimak, Michael; Sonich-Mullin, Cynthia; Soto, Vicki; Stewart, Andrew; Suarez, Luis; Teichman, Kevin; Trovato, Ramona; Vandegrift, Steve; Vandenberg, John; vanDrunick, Suzanne; Wilson, Scott; Zambrana, Jose; Zobrist, Marcus
Sent:	7/7/2015 4:36:06 PM
Subject:	HFDWA monthly call

We will be providing a short update about the rollout of the draft assessment and final ORD reports last month, as well as giving information about upcoming/ongoing activities related to the study.

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Ex. 6

Ex. 5

Please send agenda items by 4pm on Tuesday. An agenda will be sent by 9:30am the day of the meeting.
~~~~~~

From: Ridley, Caroline
To: Burgoon, Lyle
Sent: 7/7/2015 4:36:03 PM
Subject: Canceled: HFDWA monthly call

We will be providing a short update about the rollout of the draft assessment and final ORD reports last month, as well as giving information about upcoming/ongoing activities related to the study.

~~~~~~

Ex. 6

Ex. 5

Please send agenda items by 4pm on Tuesday. An agenda will be sent by 9:30am the day of the meeting.
~~~~~~

From:	Ridley, Caroline
To:	LeDuc, Stephen
Sent:	6/9/2015 3:48:41 PM
Subject:	Accepted: NCEA Presentation on Draft Hydraulic Fracturing Assessment

From: Ridley, Caroline

To: Bates, William; Beak, Doug; Bergdale, Amy; Briskin, Jeanne; Bueno, Michael; Burden, Susan; Burgoon, Lyle; Butler, Barbara; Clark, Christopher; Cluff, Maryam; Daiss, Rebecca; Dean, Jill; Deniz (Inci) Demirkanli; Fleming, Megan; Ford, Robert; Frithsen, Jeff; Gibbons, Dayna; Henderson, Michelle; Hillenbrand, Charles; Houck, Keith; Houk, Virginia; Impellitteri, Christopher; Jonathan Koplos; Ken Klewicki (Ken.Klewicki@cadmusgroup.com); Knightes, Chris; Kraemer, Stephen; Landis, Matthew; LeDuc, Stephen; Ludwig, Ralph; Mary Ellen Tuccillo; Matthews, Lisa; Meza-Cuadra, Claudia; Mravik, Susan; Oberley, Gregory; Overbay, Michael; Richards, Matthew; Roberts, Cindy; Schumacher, Brian; Shari Ring; Sharkey, Susan; Singer, Alison; Smith, Kelly; Souders, Steve; Stanek, John; Sullivan, Kate; Tinsley, Chuck; Todd, Jason; Watkins, Stephen; Weaver, Jim; Wilkin, Rick; Williams, Larke; Wiser, Nathan; Yohannes, Lia; Yost, Erin; Solomon, Sarah

CC: Auerbacher, Kevin; Bergman, Ronald; Biddle, Lisa; Carey, Kyle; Devir, Brian; Drees, Lauren; Elkins, Timothy; Ferguson, Holly; Foley, Gary; Fritz, Greg; Gillespie, Andrew; Ginsberg, Marilyn; Hanley, Adrian; Hauchman, Fred; Hyde, Tinka; Itkin, Cheryl; Jann, Stephen; Jewett, David; Johnson, Lora; Lewis, Paul; Little, Stephen; Matuszko, Jan; McDonald, Michael E.; Miller, Andy; Mottl, Nathan; Norris, Gary; Olszewski, John; ONeill, Sandra; Orme-Zavaleta, Jennifer; Pachnowski, Maya; Parikh, Pooja; Patterson, Craig; Piantanida, David; Pyne, Jaclyn; Robinson, Bonnie; Seltzer, Mark; Slimak, Michael; Sonich-Mullin, Cynthia; Soto, Vicki; Stewart, Andrew; Suarez, Luis; Teichman, Kevin; Trovato, Ramona; Vandegrift, Steve; Vandenberg, John; vanDrunick, Suzanne; Wilson, Scott; Zambrana, Jose; Zobrist, Marcus; Tong-Argao, Sania

Sent: 6/8/2015 9:39:31 AM

Subject: Canceled: HFDWA monthly call

Ex. 6

Ex. 5

Please send agenda items by 4pm on Tuesday. An agenda will be sent by 9:30am the day of the meeting.

From: Ridley, Caroline
To: Maloney, Kelsey
Sent: 6/2/2015 2:51:11 PM
Subject: Tentative: HF Study Draft Assessment Public Webinar - 2

From:	Ridley, Caroline
To:	Maloney, Kelsey
Sent:	6/2/2015 2:45:24 PM
Subject:	Tentative: HF Study Draft Assessment Public Webinar - 1

From:	Ridley, Caroline
To:	Meacham, Connie
Sent:	5/27/2015 10:24:20 AM
Subject:	Accepted: Preparing the SAB Copy of HF Report & Appendices - - & Plan of action for next week's Final Report & Final Appendices

From: Ridley, Caroline
To: Meacham, Connie
Sent: 5/26/2015 12:27:44 PM
Subject: Accepted: Phone call about the Hydraulic Fracturing Report ... Next Steps for Maureen's contractors

From:	Ridley, Caroline
To:	Bates, William; Beak, Doug; Bergdale, Amy; Briskin, Jeanne; Bueno, Michael; Burden, Susan; Burgoon, Lyle; Butler, Barbara; Clark, Christopher; Cluff, Maryam; Daiss, Rebecca; Dean, Jill; Deniz (Inci) Demirkanli; Fleming, Megan; Ford, Robert; Frithsen, Jeff; Gibbons, Dayna; Henderson, Michelle; Hillenbrand, Charles; Houck, Keith; Houk, Virginia; Impellitteri, Christopher; Jonathan Koplos; Ken Klewicki Ex. 4; Knightes, Chris; Kraemer, Stephen; Landis, Matthew; LeDuc, Stephen; Ludwig, Ralph; Mary Ellen Tuccillo; Matthews, Lisa; Meza-Cuadra, Claudia; Mravik, Susan; Oberley, Gregory; Overbay, Michael; Richards, Matthew; Roberts, Cindy; Schumacher, Brian; Shari Ring; Sharkey, Susan; Singer, Alison; Smith, Kelly; Souders, Steve; Stanek, John; Sullivan, Kate; Tinsley, Chuck; Todd, Jason; Watkins, Stephen; Weaver, Jim; Wilkin, Rick; Williams, Larke; Wiser, Nathan; Yohannes, Lia; Yost, Erin; Solomon, Sarah
CC:	Auerbacher, Kevin; Bergman, Ronald; Biddle, Lisa; Carey, Kyle; Devir, Brian; Drees, Lauren; Elkins, Timothy; Ferguson, Holly; Foley, Gary; Fritz, Greg; Gillespie, Andrew; Ginsberg, Marilyn; Hanley, Adrian; Hauchman, Fred; Hyde, Tinka; Itkin, Cheryl; Jann, Stephen; Jewett, David; Johnson, Lora; Lewis, Paul; Little, Stephen; Matuszko, Jan; McDonald, Michael E.; Miller, Andy; Mottl, Nathan; Norris, Gary; Olszewski, John; ONeill, Sandra; Orme-Zavaleta, Jennifer; Pachnowski, Maya; Parikh, Pooja; Patterson, Craig; Piantanida, David; Pyne, Jaclyn; Robinson, Bonnie; Seltzer, Mark; Slimak, Michael; Sonich-Mullin, Cynthia; Soto, Vicki; Stewart, Andrew; Suarez, Luis; Teichman, Kevin; Trovato, Ramona; Vandegrift, Steve; Vandenberg, John; vanDrunick, Suzanne; Wilson, Scott; Zambrana, Jose; Zobrist, Marcus; Tong-Argao, Sania
Sent:	5/13/2015 9:59:36 AM
Subject:	HFDWA monthly call

Today we will have a short update on the final EPA HF study products and the draft HF assessment that are scheduled to be release this month.

~~~~~~

Ex. 6

Ex. 5

Please send agenda items by 4pm on Tuesday. An agenda will be sent by 9:30am the day of the meeting.
~~~~~~

From: Ridley, Caroline
To: Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Jonathan Koplos; Yohannes, Lia; Fleming, Megan; Knightes, Chris; Shari Ring; Weaver, Jim; Cluff, Maryam; Mary Ellen Tuccillo; Stanek, John; Solomon, Sarah
Sent: 4/29/2015 9:21:22 AM
Subject: HFDWA weekly chapter leads call

Thanks for being flexible with the timing of this meeting.

Agenda

Ex. 5

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Continuation of our weekly call.

Agenda to be sent week of.
~~~~~~

From: Ridley, Caroline
CC: Jonathan Koplos
Sent: 4/28/2015 2:18:29 PM
Subject: OAR estimates of re-fracturing

Join us for a discussion of re-fracturing frequency, as estimated by OAR.
Additional perspective on fracturing in older wells will be provided by author(s) of ORD's Well File Review paper.

From: Ridley, Caroline
To: Waltzer, Suzanne; Weitz, Melissa; Macpherson, Alex; Moore, Bruce; Burden, Susan
CC: LeDuc, Stephen; Wiser, Nathan; Briskin, Jeanne; Frithsen, Jeff
Sent: 4/28/2015 11:59:08 AM
Subject: OAR estimates of re-fracturing

Join us for a discussion of re-fracturing frequency, as estimated by OAR.
Additional perspective on fracturing in older wells will be provided by author(s) of ORD's Well File Review paper.

From: Ridley, Caroline
To: Jonathan Koplos
Sent: 4/28/2015 8:52:40 AM
Subject: HFDWA chapter 2

Ex. 5

From: Ridley, Caroline
To: Jonathan Koplos
Sent: 4/27/2015 4:13:15 PM
Subject: HFDWA chapter 2

Ex. 5

From: Ridley, Caroline
To: Solomon, Sarah
Sent: 4/16/2015 10:37:22 AM
Subject: HFDWA monthly call

Ex. 6

Ex. 5

Please send agenda items by 4pm on Tuesday. An agenda will be sent by 9:30am the day of the meeting.

From:	Ridley, Caroline
To:	Bates, William; Beak, Doug; Bergdale, Amy; Briskin, Jeanne; Bueno, Michael; Burden, Susan; Burgoon, Lyle; Butler, Barbara; Clark, Christopher; Cluff, Maryam; Daiss, Rebecca; Dean, Jill; Deniz (Inci) Demirkanli; Fleming, Megan; Ford, Robert; Frithsen, Jeff; Gibbons, Dayna; Henderson, Michelle; Hillenbrand, Charles; Houck, Keith; Houk, Virginia; Impellitteri, Christopher; Jonathan Koplos; Ken Klewicki (Ex. 4; Knightes, Chris; Kraemer, Stephen; Landis, Matthew; LeDuc, Stephen; Ludwig, Ralph; Mary Ellen Tuccillo; Matthews, Lisa; Meza-Cuadra, Claudia; Mravik, Susan; Oberley, Gregory; Overbay, Michael; Richards, Matthew; Roberts, Cindy; Schumacher, Brian; Shari Ring; Sharkey, Susan; Singer, Alison; Smith, Kelly; Souders, Steve; Stanek, John; Sullivan, Kate; Tinsley, Chuck; Todd, Jason; Watkins, Stephen; Weaver, Jim; Wilkin, Rick; Williams, Larke; Wiser, Nathan; Yohannes, Lia; Yost, Erin
CC:	Auerbacher, Kevin; Bergman, Ronald; Biddle, Lisa; Carey, Kyle; Devir, Brian; Drees, Lauren; Elkins, Timothy; Ferguson, Holly; Foley, Gary; Fritz, Greg; Gillespie, Andrew; Ginsberg, Marilyn; Hanley, Adrian; Hauchman, Fred; Hyde, Tinka; Itkin, Cheryl; Jann, Stephen; Jewett, David; Johnson, Lora; Lewis, Paul; Little, Stephen; Matuszko, Jan; McDonald, Michael E.; Miller, Andy; Mottl, Nathan; Norris, Gary; Olszewski, John; ONeill, Sandra; Orme-Zavaleta, Jennifer; Pachnowski, Maya; Parikh, Pooja; Patterson, Craig; Piantanida, David; Pyne, Jaclyn; Robinson, Bonnie; Seltzer, Mark; Slimak, Michael; Sonich-Mullin, Cynthia; Soto, Vicki; Stewart, Andrew; Suarez, Luis; Teichman, Kevin; Trovato, Ramona; Vandegrift, Steve; Vandenberg, John; vanDrunick, Suzanne; Wilson, Scott; Zambrana, Jose; Zobrist, Marcus; Tong-Argao, Sania
Sent:	4/7/2015 3:43:06 PM
Subject:	HFDWA monthly call

Ex. 6

Ex. 5

Please send agenda items by 4pm on Tuesday. An agenda will be sent by 9:30am the day of the meeting.

From: Ridley, Caroline
To: Frithsen, Jeff
Sent: 4/6/2015 12:21:49 PM
Subject: Accepted: HF: Discussion of Chapter 9

From: Ridley, Caroline
To: Burke, Thomas
Sent: 3/31/2015 10:50:27 AM
Subject: Accepted: HF Drinking Water Chapter Comments: Executive Summary & chapters 6-10 (Discussion part 2 - if needed)

From: Ridley, Caroline
To: Burke, Thomas
Sent: 3/31/2015 10:47:58 AM
Subject: Accepted: HF Drinking Water Chapter Comments: Executive Summary & chapters 6-10 (Discussion part 1)

From: Ridley, Caroline
To: Burke, Thomas
Sent: 3/27/2015 1:52:38 PM
Subject: Accepted: HF Drinking Water Chapter Comments: Executive Summary & chapters 6-10 (Discussion part 1)

From: Ridley, Caroline
To: Burke, Thomas
Sent: 3/27/2015 1:14:51 PM
Subject: Accepted: HF Drinking Water Chapter Comments: Chapter 4

From:	Ridley, Caroline
To:	Burke, Thomas
Sent:	3/27/2015 1:14:39 PM
Subject:	Accepted: HF Drinking Water Chapter Comments: Executive Summary & chapters 6-10 (Discussion part 2 - if needed)

From: Ridley, Caroline
To: Burke, Thomas
Sent: 3/27/2015 1:14:21 PM
Subject: Accepted: HF Drinking Water Chapter Comments: Executive Summary & chapters 6-10 (Discussion part 1)

From:	Ridley, Caroline
To:	Burke, Thomas
Sent:	3/27/2015 1:14:09 PM
Subject:	Accepted: HF Drinking Water Chapter Comments: 1,2,3, and 5

From: Ridley, Caroline
To: Frithsen, Jeff; LeDuc, Stephen; Fleming, Megan; Weaver, Jim; Mary Ellen Tuccillo
Sent: 3/26/2015 3:20:54 PM
Subject: HF terminology: flowback, produced, wastewater

A final(?) discussion of the terms flowback, produced water, and hydraulic fracturing wastewater in the assessment.

From: Ridley, Caroline
To: Williams, Larke
Sent: 3/17/2015 11:16:01 AM
Subject: Accepted: Multiagency HF Webinar - Trends in Hydraulic Fracturing - USGS Report (For all locations, use Conference Code Ex. 6)

From: Ridley, Caroline on behalf of Williams, Larke
To: Knightes, Chris
Sent: 3/13/2015 4:45:43 PM
Subject: FW: Multiagency HF Webinar - Trends in Hydraulic Fracturing - USGS Report (For all locations, use Conference Code # Ex. 6

Really relevant to the chem mixing chapter. I would hope Larke makes sure to invite all her co-authors on the chapter, as well as all authors of the water acquisition chapter.

-----Original Appointment-----
From: Williams, Larke
Sent: Friday, February 20, 2015 4:15 PM
To: Williams, Larke; Daiss, Rebecca; Martinez, Barbara; natenna.dobson@hq.doe.gov; Elena.Melchert@hq.doe.gov; Marni.Lenahan@hq.doe.gov; Hladik, Michelle; ray.boswell@netl.doe.gov; alexandra.hakala@netl.doe.gov; roy.long@netl.doe.gov; barbara.kutchko@netl.doe.gov; JMcDaniel Ex. 4 ; cwreden Ex. 4 daniel.soeder@netl.doe.gov; Yohannes, Lia; dhayba@usgs.gov; Kelly, Brian; dakob@usgs.gov; dtillitt@usgs.gov; wilson@usgs.gov; Kraemer, Stephen; Burden, Susan; Wiser, Nathan; Dean, Jill; Hillenbrand, Charles; Tinsley, Chuck; Kumar, Chitra; Sharkey, Susan; Impellitteri, Christopher; Briskin, Jeanne; Frithsen, Jeff; Huang, Junqi; Schumacher, Brian; Gilliland, Alice; Weaver, Jim; Moore, Bruce; Bates, William; Kobelski, Bruce; Biddle, Lisa; Landis, Matthew; Cluff, Maryam; Fleming, Megan; Roberts, Cindy; Burgoon, Lyle; Stanek, John; Bergman, Ronald; Carey, Kyle; Moriarty, Edward; Shekar, Navin; Pritts, Jesse; vanDrunick, Suzanne; McDonald, Michael E.; Gillespie, Andrew; Teichman, Kevin; Egidi, Philip; Peake, Tom; Schultheisz, Daniel; Comerford, Sherri; Lazorchak, Jim; Sullivan, Kate; McFadden, Angela; Godfrey, Annie; Allenbach, Becky; Blanco-Gonzalez, Joel; Cantilli, Robert; Harper, Cecelia; Olone, Dan; Phillips, David; Durkee, Stanley; Doyle, Elizabeth; Faison, Brendlyn; Farrell, Robbi; Fried, Gregory; Green, Holly; Hopkins, Marion; Faulk, Jack; Harris, Jamie S.; Alicea, Jezebele; Shell, Karrie-Jo; Nuhfer, Mark; Elovitz, Michael; Schutz, Michelle; Muse, Mike; Eisenberg, Mindy; O'Mara, Kate; Ramasamy, Santhini; Burns, Robert; Olive, Robert; Danesi, Robin; Jordan, Ronald; Burke, Shaun; Regli, Stig; Grubbs, Thomas; binetti, victoria; Gray, Wendy; Arguto, William; Zimmer, Andrea; Zobrist, Marcus; Pickrel, Jan; Smith, Kelly; Jollie, Jeff; Brune, Doug; McManus, Fred; Cole, Larry; Ridley, Caroline; Kazior, Kathryn; LeDuc, Stephen; Rodgers-Jenkins, Crystal; Sidle, Roy; Ginsberg, Marilyn; Staples, Bridget; GJMoridis@lbl.gov; MTReagan@lbl.gov; Shari.Ring Ex. 6 Brian.Strazisar@netl.doe.gov; ICOZZARE@USGS.GOV; David Russ (druss@usgs.gov); Vivian Nolan (vpnolan@usgs.gov); guido.dehoratiis@hq.doe.gov; Branby, Jill; Singer, Alison; Zambrana, Jose; Seiwert, Carla; Livingood, Marilyn; Platt, Steve; Reinhart, Roger; Bennett, James; Poe, Brian; Cohen, Amy; Johnson, KarenD; Williams, Connor; Brian Varela; Tanya Gallegos; Herman, Janet; Miller, Aubrey (NIH/NIEHS) [E]; Aida M Farag; Orazio, Carl; Haefner, Ralph; Delzer, Gregory; Karl Schroeder; Mike Focazio; See, Randolph; Eric Smistad; grant.bromhal@netl.doe.gov; Wilson, Scott; Robert Dilmore; Elskus, Adria; richard.hammack@netl.doe.gov
Cc: Johnson, Brent; Graff, Michelle; Colombo, Matt; Bayer, MaryRose; Moore, Keara; Kelly, Suzanne
Subject: Multiagency HF Webinar - Trends in Hydraulic Fracturing - USGS Report (For all locations, use Conference Code #: Ex. 6
When: Wednesday, March 18, 2015 2:00 PM-3:30 PM (UTC-05:00) Eastern Time (US & Canada).
Where: Information to follow

As part of the Multiagency Collaboration on Unconventional Oil and Gas (UOG) Research, the 3 agencies - USGS, DOE, and EPA - are setting up informational webinars on USGS's recently released "Trends in Hydraulic Fracturing Distributions and Treatment Fluids, Additives, Proppants, and Water Volumes Applied to Wells Drilled in the United States from 1947 through 2010 - Data Analysis and Comparison to the Literature." The authors, Tanya J. Gallegos and Brian A. Varela, will describe their work and provide staff an opportunity to ask questions. Please share this invitation with interested staff from your office. The webinar is scheduled for Wednesday, March 18 @ 2:00 pm EST.

Date: March 18
Time: 2:00 - 3:00 pm EST (1 hour presentation followed by 30 minutes Q&A)
Webinar on: "Trends in Hydraulic Fracturing Distributions and Treatment Fluids, Additives, Proppants, and Water Volumes Applied to Wells Drilled in the United States from 1947 through 2010 - Data Analysis and Comparison to the Literature"

Authors: Tanya J. Gallegos and Brian A. Varela

Ex. 5

Phone bridge: *
From the National Center in Reston, dial internally x4848
From all other USGS/DOI locations, dial 703-648-4848
From non-DOI locations, dial toll free 855-547-8255

* For all locations, use Conference Code #: Ex. 5

For Reston participants: Conference room 3B452/3B457

Report available from: http://pubs.usgs.gov/sir/2014/5131/

Author bios:
Tanya J. Gallegos is a research engineer with the Eastern Energy Resource Science Center at the U.S. Geological Survey in Reston, VA. She received a Ph.D. in Environmental and Water Resources Engineering 2007 from the University of Michigan. She is a registered Professional Engineer in the State of New Mexico. Her research encompasses field and lab studies to understand environmental implications of energy development on natural resources throughout the hydraulic fracturing and uranium mining and milling life cycles. Research topics include solid-phase characterization; geochemical and isotopic signatures of tight oil- and uranium-related waters; development of novel methods for groundwater remediation of trace elements and inorganics; identification of metrics for integrated assessments for energy resource development; and assessing water use in energy resource development.

Brian A. Varela is a computer scientist with the Central Energy Resources Science Center at the U.S. Geological Survey, specializing in coding programs to compile oil and gas well data from the IHS Petroleum Information Data Database, developing functions for Excel and Access, and GIS mapping. Brian has contributed to the Produced Waters Project, Carbon Sequestration project, and two hydraulic fracturing related studies conducted with the USGS John Wesley Powell Center for Synthesis and Analysis. In addition to compiling the historical data on hydraulic fracturing from 1947-2010, other recent projects related to hydraulic fracturing include the compilation of hydraulic fracturing injection well data for a small part of Texas to examine induced seismicity. Brian also has created programs to calculate water-to-oil and water-to-gas, flowback, and recovery ratios for hydraulically fractured wells completed in the Bakken and the Niobrara formations. He has also written programs to estimate horizontal well lateral dimensions.

From: Ridley, Caroline
To: Williams, Larke
Sent: 3/12/2015 9:36:42 AM
Subject: Tentative: Multiagency HF Webinar - Trends in Hydraulic Fracturing - USGS Report (For all locations, use Conference Code #: Ex. 6

From:	Ridley, Caroline
To:	Bates, William; Beak, Doug; Bergdale, Amy; Briskin, Jeanne; Bueno, Michael; Burden, Susan; Burgoon, Lyle; Butler, Barbara; Clark, Christopher; Cluff, Maryam; Daiss, Rebecca; Dean, Jill; Deniz (Inci) Demirkanli; Fleming, Megan; Ford, Robert; Frithsen, Jeff; Gibbons, Dayna; Henderson, Michelle; Hillenbrand, Charles; Houck, Keith; Houk, Virginia; Impellitteri, Christopher; Jonathan Koplos; Ken Klewicki Ex. 4; Knightes, Chris; Kraemer, Stephen; Landis, Matthew; LeDuc, Stephen; Ludwig, Ralph; Mary Ellen Tuccillo; Matthews, Lisa; Meza-Cuadra, Claudia; Mravik, Susan; Oberley, Gregory; Overbay, Michael; Richards, Matthew; Roberts, Cindy; Schumacher, Brian; Shari Ring; Sharkey, Susan; Singer, Alison; Smith, Kelly; Souders, Steve; Stanek, John; Sullivan, Kate; Tinsley, Chuck; Todd, Jason; Watkins, Stephen; Weaver, Jim; Wilkin, Rick; Williams, Larke; Wiser, Nathan; Yohannes, Lia; Yost, Erin
CC:	Tong-Argao, Sania; Pritts, Jesse; Auerbacher, Kevin; Bergman, Ronald; Biddle, Lisa; Carey, Kyle; Devir, Brian; Drees, Lauren; Elkins, Timothy; Ferguson, Holly; Foley, Gary; Fritz, Greg; Gillespie, Andrew; Ginsberg, Marilyn; Hanley, Adrian; Hauchman, Fred; Hyde, Tinka; Itkin, Cheryl; Jann, Stephen; Jewett, David; Johnson, Lora; Lewis, Paul; Little, Stephen; Matuszko, Jan; McDonald, Michael E.; Miller, Andy; Mottl, Nathan; Norris, Gary; Olszewski, John; ONeill, Sandra; Orme-Zavaleta, Jennifer; Pachnowski, Maya; Parikh, Pooja; Patterson, Craig; Piantanida, David; Pyne, Jaclyn; Robinson, Bonnie; Seltzer, Mark; Slimak, Michael; Sonich-Mullin, Cynthia; Soto, Vicki; Stewart, Andrew; Suarez, Luis; Teichman, Kevin; Trovato, Ramona; Vandegrift, Steve; Vandenberg, John; vanDrunick, Suzanne; Wilson, Scott; Zambrana, Jose; Zobrist, Marcus
Sent:	3/11/2015 10:45:33 AM
Subject:	Canceled: HFDWA monthly call

Ex. 6

Ex. 5

Please send agenda items by 4pm on Tuesday. An agenda will be sent by 9:30am the day of the meeting.

From: Ridley, Caroline on behalf of Yohannes, Lia
To: Jonathan Koplos; Shari Ring; Knightes, Chris; Mary Ellen Tuccillo; Stanek, John; Weaver, Jim
Sent: 3/9/2015 9:10:35 AM
Subject: FW: HF Team Meeting

Ex. 5

-----Original Appointment-----
From: Yohannes, Lia
Sent: Friday, February 13, 2015 8:48 AM
To: Yohannes, Lia; Briskin, Jeanne; Burden, Susan; Daiss, Rebecca; Gibbons, Dayna; Matthews, Lisa; Roberts, Cindy; Sharkey, Susan; Tinsley, Chuck; Watkins, Stephen; Wiser, Nathan; Frithsen, Jeff; LeDuc, Stephen; Cluff, Maryam; Singer, Alison; Williams, Larke; Bueno, Michael; Fleming, Megan; Ridley, Caroline; Dean, Jill; Corona, Elizabeth; Hubbard, Carolyn
Cc: Maloney, Kelsey
Subject: HF Team Meeting
When: Tuesday, March 10, 2015 10:30 AM-11:30 AM (UTC-05:00) Eastern Time (US & Canada).
Where: DCRoomRRB51161

Hi all,

We're moving this meeting up to 10:30am for this week.

Thanks!

Ex. 6

From: Ridley, Caroline
To: Jonathan Koplos; Mary Ellen Tuccillo; Frithsen, Jeff
Sent: 3/3/2015 12:56:28 PM
Subject: HFDWA wastewater work
Attachments: **Ex. 5**

We will be talking about the follow-on list of tasks in the attached document, as well as Keven Teichman's review comments.

Lead Region Report – July 2015
Region 4: Lead Region for Office of Water

Recent Activities

Non-Responsive

Ex. 5

Non-Responsive

Non-Responsive

To: Auerbacher, Kevin[Auerbacher.Kevin@epa.gov]
Cc: Wehling, Carrie[Wehling.Carrie@epa.gov]
From: Parikh, Pooja
Sent: Thur 2/19/2015 7:00:43 PM
Subject: RE: Correspondence from Congressman Ron DeSantis

Ex. 5

Thanks for the heads-up. **Ex. 5**

Ex. 5

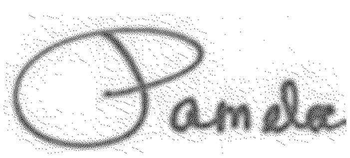
From: Auerbacher, Kevin
Sent: Thursday, February 19, 2015 1:40 PM
To: Parikh, Pooja
Subject: FW: Correspondence from Congressman Ron DeSantis

Ex. 5

From: Janifer, Pamela
Sent: Thursday, February 19, 2015 1:36 PM
To: Greene, Ashley
Cc: Peck, Gregory; Hanley, Mary; Auerbacher, Kevin; Emmerson, Caroline; Perry, Dale
Subject: Correspondence from Congressman Ron DeSantis

Ex. 5

Ex. 5



Pamela Janifer

U.S. Environmental Protection Agency • Office of Congressional and Intergovernmental Relations

1200 Pennsylvania Ave, NW | Washington, DC 20460 | **Office:** 202.564.6969 | **Fax:** 202.501.1550 | **Email:** janifer.pamela@epa.gov

To: Briskin, Jeanne[Briskin.Jeanne@epa.gov]
From: Houge, Rachel
Sent: Fri 6/12/2015 3:29:05 PM
Subject: RE: Questions from OMB re HF and Questions for the Record

Thank you Jeanne!

Rachel Houge

Office of Research and Development/EPA Gulf of Mexico Program

202-280-8411

From: Briskin, Jeanne
Sent: Friday, June 12, 2015 10:06 AM
To: Lang, Jamie; Richards, Matthew; Houge, Rachel; Richards, Matthew; Houge, Rachel
Cc: Corona, Elizabeth; Gwinn, Maureen; Smith, Kelley; Frithsen, Jeff; Gonzalez, Daniel; Teichman, Kevin; Battaglia, Amy; Gibbons, Dayna; Matthews, Lisa; Hauchman, Fred
Subject: RE: Questions from OMB re HF and Questions for the Record

Ex. 5

From: Frithsen, Jeff
Sent: Thursday, June 11, 2015 1:29 PM
To: Lang, Jamie; Briskin, Jeanne; Teichman, Kevin
Cc: Corona, Elizabeth; Gwinn, Maureen; Smith, Kelley; Gonzalez, Daniel; Battaglia, Amy; Gibbons, Dayna; Richards, Matthew; Houge, Rachel; Matthews, Lisa
Subject: RE: Questions from OMB re HF and Questions for the Record

Hello:

Ex. 5

Thanks all. Feel free to give me a call if anything needs discussion. Cell number is Ex. 6
Ex. 6

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Lang, Jamie
Sent: Wednesday, June 10, 2015 12:02 PM
To: Frithsen, Jeff; Briskin, Jeanne; Teichman, Kevin
Cc: Corona, Elizabeth; Gwinn, Maureen; Smith, Kelley; Gonzalez, Daniel; Battaglia, Amy; Gibbons, Dayna; Richards, Matthew; Houge, Rachel
Subject: FW: Questions from OMB re HF and Questions for the Record

Hi all,

Ex. 5

Thanks!

Jamie

Jamie A. Lang

Branch Chief, Planning, Budget, and Performance Analysis Branch

Office of Program Accountability and Resource Management

Office Of Research and Development, US EPA

303-462-9063 (W)

Ex. 6

202-564-8347 (DC office)

From: Lang, Jamie
Sent: Monday, June 08, 2015 10:19 AM
To: Frithsen, Jeff; Briskin, Jeanne; Teichman, Kevin
Cc: Corona, Elizabeth; Gwinn, Maureen; Smith, Kelley; Gonzalez, Daniel; Battaglia, Amy; Gibbons, Dayna; Richards, Matthew
Subject: FW: Questions from OMB re HF and Questions for the Record

Hi all,

Ex. 5

Ex. 5

Thanks!

Jamie

Jamie A. Lang

Branch Chief, Planning, Budget, and Performance Analysis Branch

Office of Program Accountability and Resource Management

Office Of Research and Development, US EPA

303-462-9063 (W)

Ex. 6

202-564-8347 (DC office)

From: Gonzalez, Daniel
Sent: Tuesday, June 02, 2015 12:53 PM
To: Kadeli, Lek; Frithsen, Jeff
Cc: Lang, Jamie; Kavlock, Robert; Briskin, Jeanne; Teichman, Kevin; Corona, Elizabeth; Gwinn, Maureen; Smith, Kelley; Battaglia, Amy; Gibbons, Dayna; Richards, Matthew
Subject: RE: Questions from OMB re HF and Questions for the Record

Ex. 5

Dan

Daniel K Gonzalez, Senior Budget Officer

Office of Research and Development

Division Director

Resources Planning, Performance, and Budget Policy Division

Phone: 202-564-2877

Ex. 6

Room #: RRB 41189

Mail Code: 8102R

From: Kadeli, Lek
Sent: Tuesday, June 02, 2015 2:52 PM
To: Frithsen, Jeff
Cc: Lang, Jamie; Kavlock, Robert; Briskin, Jeanne; Teichman, Kevin; Corona, Elizabeth; Gwinn, Maureen; Smith, Kelley; Gonzalez, Daniel; Battaglia, Amy; Gibbons, Dayna; Richards, Matthew
Subject: Re: Questions from OMB re HF and Questions for the Record

Ex. 5

Acting Assistant Administrator

Office of Research and Development

Environmental Protection Agency

Washington D.C.

(202)564-6620

On Jun 2, 2015, at 2:48 PM, Frithsen, Jeff <Frithsen.Jeff@epa.gov> wrote:

Jamie:

Ex. 5

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Lang, Jamie
Sent: Tuesday, June 02, 2015 2:45 PM
To: Kadeli, Lek; Kavlock, Robert; Frithsen, Jeff; Briskin, Jeanne; Teichman, Kevin
Cc: Corona, Elizabeth; Gwinn, Maureen; Smith, Kelley; Gonzalez, Daniel; Battaglia, Amy; Gibbons, Dayna; Richards, Matthew
Subject: Questions from OMB re HF and Questions for the Record

Hello All,

Ex. 5

Thanks!

Jamie

Jamie A. Lang

Branch Chief, Planning, Budget, and Performance Analysis Branch

Office of Program Accountability and Resource Management

Office Of Research and Development, US EPA

303-462-9063 (W)

Ex. 6

202-564-8347 (DC office)

From: Newsom, Brandon
Sent: Tuesday, June 02, 2015 12:08 PM
To: Gonzalez, Daniel; Lang, Jamie
Cc: Boyd, Wyatt
Subject: HF Study/QFRs Update

Dan/Jamie,

Ex. 5

Thanks!

Brandon Newsom

Program Analyst • Office of the Chief Financial Officer / Office of Budget

Office: 202.564.1405 | **Email:** newsom.brandon@epa.gov |

To: Richards, Matthew[Richards.Matthew@epa.gov]; Frithsen, Jeff[Frithsen.Jeff@epa.gov]
From: Briskin, Jeanne
Sent: Mon 6/15/2015 2:38:01 PM
Subject: RE: Please review: OMB Comments on HF QFRs

Ex. 5

From: Richards, Matthew
Sent: Monday, June 15, 2015 10:37 AM
To: Frithsen, Jeff
Cc: Briskin, Jeanne
Subject: Fw: Please review: OMB Comments on HF QFRs

Ex. 5

Matt Richards

Office: 202.564.5629 (Weds - Fri)

Ex. 6

From: Gibbons, Dayna
Sent: Monday, June 15, 2015 10:30
To: Richards, Matthew; Burke, Thomas; Kadeli, Lek; Kavlock, Robert
Cc: Deener, Kathleen; Teichman, Kevin; Corona, Elizabeth; Gwinn, Maureen; Piantanida, David; Hubbard, Carolyn; Battaglia, Amy; Gonzalez, Daniel; Houge, Rachel
Subject: RE: Please review: OMB Comments on HF QFRs

Ex. 5

From: Richards, Matthew
Sent: Monday, June 15, 2015 10:11 AM

To: Burke, Thomas; Kadeli, Lek; Kavlock, Robert
Cc: Deener, Kathleen; Teichman, Kevin; Gibbons, Dayna; Corona, Elizabeth; Gwinn, Maureen; Piantanida, David; Hubbard, Carolyn; Battaglia, Amy; Gonzalez, Daniel; Houge, Rachel
Subject: Re: Please review: OMB Comments on HF QFRs

Morning everyone-

Ex. 5

Thank you,

Matt Richards

Office: 202.564.5629 (Weds - Fri)

Ex. 6

From: Houge, Rachel
Sent: Friday, June 12, 2015 12:10
To: Burke, Thomas; Kadeli, Lek; Kavlock, Robert
Cc: Deener, Kathleen; Teichman, Kevin; Briskin, Jeanne; Williams, Larke; Gibbons, Dayna; Corona, Elizabeth; Gwinn, Maureen; Piantanida, David; Hubbard, Carolyn; Battaglia, Amy; Gonzalez, Daniel; Frithsen, Jeff; Richards, Matthew; Lang, Jamie
Subject: Please review: OMB Comments on HF QFRs

Good Afternoon-

Ex. 5

Thank you,

Rachel

Rachel Houge

Office of Research and Development/EPA Gulf of Mexico Program

202-280-8411

To: Frithsen, Jeff[Frithsen.Jeff@epa.gov]; Briskin, Jeanne[Briskin.Jeanne@epa.gov]
Cc: Teichman, Kevin[Teichman.Kevin@epa.gov]; Williams, Larke[Williams.Larke@epa.gov]; Burden, Susan[Burden.Susan@epa.gov]; Yohannes, Lia[Yohannes.Lia@epa.gov]; Gibbons, Dayna[Gibbons.Dayna@epa.gov]; Piantanida, David[Piantanida.David@epa.gov]; Battaglia, Amy[Battaglia.Amy@epa.gov]; Gonzalez, Daniel[Gonzalez.Daniel@epa.gov]; Richards, Matthew[Richards.Matthew@epa.gov]; Smith, Kelley[Smith.Kelley@epa.gov]; Gwinn, Maureen[gwinn.maureen@epa.gov]; Corona, Elizabeth[Corona.Elizabeth@epa.gov]
From: Lang, Jamie
Sent: Tue 3/24/2015 7:51:51 PM
Subject: House Appropriation Questions for the Record DUE: COB THURSDAY MARCH 26th

Ex. 5

Jeff and Jeanne,

Ex. 5

Thanks,

Jamie

Jamie A. Lang

Branch Chief, Planning, Budget, and Performance Analysis Branch

Office of Program Accountability and Resource Management

Office Of Research and Development, US EPA

303-462-9063 (W)

Ex. 6

202-564-8347 (DC office)

To: Gibbons, Dayna[Gibbons.Dayna@epa.gov]
Cc: Briskin, Jeanne[Briskin.Jeanne@epa.gov]; Burden, Susan[Burden.Susan@epa.gov]
From: Hauchman, Fred
Sent: Tue 2/17/2015 9:12:54 PM
Subject: Re: Comments on comms materials

Ex. 5

Dayna,

Ex. 5

Fred

From: Jbriskin <**Ex. 6**
Sent: Tuesday, February 17, 2015 2:18 PM
To: Gibbons, Dayna
Cc: Hauchman, Fred
Subject: Fwd: Comments on comms materials

Adding dayna

Ex. 5

Begin forwarded message:

From: J Briskin **Ex. 6**
Date: February 16, 2015 at 10:26:45 PM EST
To: Jeanne Briskin <briskin.jeanne@epa.gov>, "Burden, Susan" <burden.susan@epa.gov>, Fred Hauchman <Hauchman.Fred@epamail.epa.gov>, Jill Dean <dean.jill@epa.gov>
Subject: Comments on comms materials

Ex. 5

To: Smith, Kelley[Smith.Kelley@epa.gov]
Cc: Corona, Elizabeth[Corona.Elizabeth@epa.gov]; Deener, Kathleen[Deener.Kathleen@epa.gov]; Richards, Matthew[Richards.Matthew@epa.gov]; Burke, Thomas[Burke.Thomas@epa.gov]; Kadeli, Lek[Kadeli.Lek@epa.gov]; Teichman, Kevin[Teichman.Kevin@epa.gov]; Gibbons, Dayna[Gibbons.Dayna@epa.gov]; Gwinn, Maureen[gwinn.maureen@epa.gov]; Piantanida, David[Piantanida.David@epa.gov]; Hubbard, Carolyn[Hubbard.Carolyn@epa.gov]; Battaglia, Amy[Battaglia.Amy@epa.gov]; Gonzalez, Daniel[Gonzalez.Daniel@epa.gov]; Houge, Rachel[Houge.Rachel@epa.gov]; Briskin, Jeanne[Briskin.Jeanne@epa.gov]; Frithsen, Jeff[Frithsen.Jeff@epa.gov]
From: Kavlock, Robert
Sent: Mon 6/22/2015 12:05:10 PM
Subject: Re: Please review: OMB Comments on HF QFRs

Ex. 5

Sent from my iPhone

On Jun 16, 2015, at 9:55 PM, Smith, Kelley <Smith.Kelley@epa.gov> wrote:

Ex. 5

Ex. 5

Ex. 5

Best,

KS

Kelley Smith

Program Advisor

Office of Research and Development

Environmental Protection Agency

202.564.2308 (Desk)

Ex. 6

Smith.Kelley@epa.gov

From: Smith, Kelley
Sent: Tuesday, June 16, 2015 2:48 PM
To: Corona, Elizabeth; Deener, Kathleen; Kavlock, Robert; Richards, Matthew
Cc: Burke, Thomas; Kadeli, Lek; Teichman, Kevin; Gibbons, Dayna; Gwinn, Maureen; Piantanida, David; Hubbard, Carolyn; Battaglia, Amy; Gonzalez, Daniel; Houge, Rachel; Briskin, Jeanne; Frithsen, Jeff
Subject: RE: Please review: OMB Comments on HF QFRs

Ex. 5

Ex. 5

Best,

KS

Kelley Smith

Program Advisor

Office of Research and Development

Environmental Protection Agency

202.564.2308 (Desk)

Ex. 6

Smith.Kelley@epa.gov

From: Smith, Kelley
Sent: Tuesday, June 16, 2015 2:08 PM
To: Corona, Elizabeth; Deener, Kathleen; Kavlock, Robert; Richards, Matthew
Cc: Burke, Thomas; Kadeli, Lek; Teichman, Kevin; Gibbons, Dayna; Gwinn, Maureen; Piantanida, David; Hubbard, Carolyn; Battaglia, Amy; Gonzalez, Daniel; Houge, Rachel; Briskin, Jeanne; Frithsen, Jeff
Subject: RE: Please review: OMB Comments on HF QFRs
Importance: High

All,

Ex. 5

Best,

KS

Kelley Smith

Program Advisor

Office of Research and Development

Environmental Protection Agency

202.564.2308 (Desk)

Ex. 6

Smith.Kelley@epa.gov

From: Corona, Elizabeth
Sent: Tuesday, June 16, 2015 10:34 AM
To: Smith, Kelley; Deener, Kathleen; Kavlock, Robert; Richards, Matthew
Cc: Burke, Thomas; Kadeli, Lek; Teichman, Kevin; Gibbons, Dayna; Gwinn, Maureen; Piantanida, David; Hubbard, Carolyn; Battaglia, Amy; Gonzalez, Daniel; Houge, Rachel; Briskin, Jeanne; Frithsen, Jeff
Subject: RE: Please review: OMB Comments on HF QFRs

Ex. 5

--

Elizabeth Corona, Ph.D. 🚲 EPA|ORD 🚲 Special Assistant / Immediate Office 🚲

(Desk) 202-564-8356 – Ex. 6

From: Smith, Kelley

Sent: Monday, June 15, 2015 4:09 PM
To: Deener, Kathleen; Kavlock, Robert; Richards, Matthew
Cc: Burke, Thomas; Kadeli, Lek; Teichman, Kevin; Gibbons, Dayna; Corona, Elizabeth; Gwinn, Maureen; Piantanida, David; Hubbard, Carolyn; Battaglia, Amy; Gonzalez, Daniel; Houge, Rachel; Briskin, Jeanne; Frithsen, Jeff
Subject: RE: Please review: OMB Comments on HF QFRs

All,

Ex. 5

Ex. 5

Ex. 5

Best,

KS

Kelley Smith

Program Advisor

Office of Research and Development

Environmental Protection Agency

202.564.2308 (Desk)

Ex. 6

Smith.Kelley@epa.gov

From: Deener, Kathleen
Sent: Monday, June 15, 2015 3:30 PM

To: Kavlock, Robert; Richards, Matthew
Cc: Burke, Thomas; Kadeli, Lek; Teichman, Kevin; Gibbons, Dayna; Corona, Elizabeth; Gwinn, Maureen; Piantanida, David; Hubbard, Carolyn; Battaglia, Amy; Gonzalez, Daniel; Houge, Rachel; Briskin, Jeanne; Frithsen, Jeff; Smith, Kelley
Subject: RE: Please review: OMB Comments on HF QFRs

Ex. 5

Ex. 5

Ex. 5

Kacee Deener, MPH

Office of Research and Development

(ph) 202.564.1990 | (mobile Ex. 6

deener.kathleen@epa.gov

From: Kavlock, Robert
Sent: Monday, June 15, 2015 2:47 PM
To: Richards, Matthew
Cc: Burke, Thomas; Kadeli, Lek; Deener, Kathleen; Teichman, Kevin; Gibbons, Dayna; Corona, Elizabeth; Gwinn, Maureen; Piantanida, David; Hubbard, Carolyn; Battaglia, Amy; Gonzalez, Daniel; Houge, Rachel; Briskin, Jeanne; Frithsen, Jeff
Subject: Re: Please review: OMB Comments on HF QFRs

Ex. 5

Ex. 5

On Jun 15, 2015, at 7:12 PM, Richards, Matthew <Richards.Matthew@epa.gov> wrote:

Ex. 5

Thank you everyone,

Matt Richards

Office: 202.564.5629 (Weds - Fri)

Cell: Ex. 6

From: Richards, Matthew
Sent: Monday, June 15, 2015 10:11
To: Burke, Thomas; Kadeli, Lek; Kavlock, Robert
Cc: Deener, Kathleen; Teichman, Kevin; Gibbons, Dayna; Corona, Elizabeth; Gwinn, Maureen; Piantanida, David; Hubbard, Carolyn; Battaglia, Amy; Gonzalez, Daniel; Houge, Rachel
Subject: Re: Please review: OMB Comments on HF QFRs

Ex. 5

Thank you,

Matt Richards

Office: 202.564.5629 (Weds - Fri)

Cell: Ex. 6

From: Houge, Rachel
Sent: Friday, June 12, 2015 12:10
To: Burke, Thomas; Kadeli, Lek; Kavlock, Robert
Cc: Deener, Kathleen; Teichman, Kevin; Briskin, Jeanne; Williams, Larke; Gibbons, Dayna; Corona, Elizabeth; Gwinn, Maureen; Piantanida, David; Hubbard, Carolyn; Battaglia, Amy; Gonzalez, Daniel; Frithsen, Jeff; Richards, Matthew; Lang, Jamie
Subject: Please review: OMB Comments on HF QFRs

Good Afternoon-

Ex. 5

Thank you,

Rachel

Rachel Houge

Office of Research and Development/EPA Gulf of Mexico Program

202-280-8411

Ex. 5

Ex. 5

To: Burke, Thomas[Burke.Thomas@epa.gov]
From: Smith, Kelley
Sent: Fri 3/27/2015 9:28:03 PM
Subject: FW: House Appropriation Questions for the Record DUE: COB THURSDAY MARCH 26th

Ex. 5

Best,

KS

Kelley Smith

Program Advisor

Office of Research and Development

Environmental Protection Agency

202.564.2308 (Desk)

Ex. 6

Smith.Kelley@epa.gov

From: Lang, Jamie
Sent: Tuesday, March 24, 2015 3:52 PM
To: Frithsen, Jeff; Briskin, Jeanne
Cc: Teichman, Kevin; Williams, Larke; Burden, Susan; Yohannes, Lia; Gibbons, Dayna; Piantanida, David; Battaglia, Amy; Gonzalez, Daniel; Richards, Matthew; Smith, Kelley; Gwinn, Maureen; Corona, Elizabeth
Subject: House Appropriation Questions for the Record DUE: COB THURSDAY MARCH 26th
Importance: High

Jeff and Jeanne,

Ex. 5

Please let us know if you have any questions.

Thanks,

Jamie

Jamie A. Lang

Branch Chief, Planning, Budget, and Performance Analysis Branch

Office of Program Accountability and Resource Management

Office Of Research and Development, US EPA

303-462-9063 (W)

Ex. 6

202-564-8347 (DC office)

From: Frithsen, Jeff
Location: Ex. 6
Importance: High
Subject: HFDWA: Approps staffers briefing
Start Date/Time: Fri 6/5/2015 8:00:00 PM
End Date/Time: Fri 6/5/2015 9:00:00 PM

From: Piantanida, David
Sent: Thursday, June 04, 2015 5:28 PM
To: Frithsen, Jeff; Kadeli, Lek
Cc: Gibbons, Dayna; Blackburn, Elizabeth; Corona, Elizabeth; Gentry, Nathan
Subject: FW: How about 4:00 on Friday?

Importance: High

Jeff and Lek - it is set for 4:00 tomorrow as a call with the Approps. staffers. See call-in details below. Ed will not be on the call - but Jim Blizzard from OCIR will be on it - and if you want me on the call, let me know.

Ex. 6

Nathan - please block this time on their calendars.

Thanks,

David Piantanida, (202) 564-8318, Ex. 6

Senior Advisor

Office of Research and Development

U.S. Environmental Protection Agency

From: Walsh, Ed
Sent: Thursday, June 04, 2015 5:23 PM
To: Piantanida, David; Blizzard, James
Subject: RE: How about 4:00 on Friday?

David

I need to set this up as a phone call for 4pm tomorrow… can you please get this on Lek and Jeff's calendar.

Ex. 6

Jim will use my leader pin to open the line.

From: Piantanida, David
Sent: Thursday, June 04, 2015 2:18 PM
To: Walsh, Ed; Blizzard, James
Subject: RE: How about 4:00 on Friday?

Non-Responsive

From: Walsh, Ed
Sent: Thursday, June 04, 2015 2:18 PM
To: Piantanida, David; Blizzard, James
Subject: RE: How about 4:00 on Friday?

Non-Responsive

From: Piantanida, David
Sent: Thursday, June 04, 2015 2:17 PM
To: Walsh, Ed; Blizzard, James
Subject: RE: How about 4:00 on Friday?

Non-Responsive

David Piantanida, (202) 564-8318, cell: Ex. 6

Senior Advisor

Office of Research and Development

U.S. Environmental Protection Agency

From: Walsh, Ed
Sent: Thursday, June 04, 2015 12:26 PM
To: Piantanida, David; Blizzard, James
Subject: RE: Final- HF Study News Release, 12 PM

David

Non-Responsive

Thanks

Ed

From: Piantanida, David
Sent: Thursday, June 04, 2015 11:45 AM
To: Blizzard, James
Cc: Walsh, Ed
Subject: Re: Final- HF Study News Release, 12 PM

Ex. 5

David Piantanida, 202-564-8318

US EPA

Office of Research and Development

Ex. 6

Sent from my iPhone

On Jun 4, 2015, at 11:44 AM, Blizzard, James <Blizzard.James@epa.gov> wrote:

Non-Responsive

From: Piantanida, David
Sent: Thursday, June 04, 2015 11:44 AM
To: Walsh, Ed
Cc: Blizzard, James
Subject: Fwd: Final- HF Study News Release, 12 PM

Here is the final release.

David Piantanida, 202-564-8318

US EPA

Office of Research and Development

Ex. 6

Sent from my iPhone

Begin forwarded message:

> **From:** "Allen, Laura" <Allen.Laura@epa.gov>
> **Date:** June 4, 2015 at 11:34:11 AM EDT
> **To:** "Daguillard, Robert" <Daguillard.Robert@epa.gov>, AO OPA OMR 60 Minute Warning <AO_OPA_OMR_60_Minute_Warning@epa.gov>
> **Subject: Final- HF Study News Release, 12 PM**
>
> Hi all- the final version of the press release is below and it will be sent at noon today. Thanks!
>
> Laura Allen
>
> Deputy Press Secretary
> Office of the Administrator
> U.S. Environmental Protection Agency
>
> Email: Allen.Laura@epa.gov
>
> Office: 202-564-1175
>
> Ex. 6
>
> Please consider the environment before printing this email.

Contact: (News Media Only)

Cathy Milbourn

(202) 564-7849

Ex. 6

milbourn.cathy@epa.gov

Ex. 5

Ex. 5

Ex. 5

To: Frithsen, Jeff[Frithsen.Jeff@epa.gov]
Cc: Kadeli, Lek[Kadeli.Lek@epa.gov]; Gibbons, Dayna[Gibbons.Dayna@epa.gov]; Hubbard, Carolyn[Hubbard.Carolyn@epa.gov]; Blackburn, Elizabeth[Blackburn.Elizabeth@epa.gov]; Battaglia, Amy[Battaglia.Amy@epa.gov]
From: Piantanida, David
Sent: Thur 6/4/2015 5:26:31 PM
Subject: Appropriations Staff briefing on Friday

Jeff,

Please remind me – what times do you have available tomorrow to do a hill staff briefing with the Appropriations folks?

Thanks,

David Piantanida, (202) 564-8318, cell: Ex. 6

Senior Advisor

Office of Research and Development

U.S. Environmental Protection Agency

From: Walsh, Ed
Sent: Thursday, June 04, 2015 12:26 PM
To: Piantanida, David; Blizzard, James
Subject: RE: Final- HF Study News Release, 12 PM

David

Non-Responsive

Thanks

Ed

From: Piantanida, David
Sent: Thursday, June 04, 2015 11:45 AM
To: Blizzard, James
Cc: Walsh, Ed
Subject: Re: Final- HF Study News Release, 12 PM

Non-Responsive

David Piantanida, 202-564-8318

US EPA

Office of Research and Development

Ex. 6

Sent from my iPhone

On Jun 4, 2015, at 11:44 AM, Blizzard, James <Blizzard.James@epa.gov> wrote:

Non-Responsive

From: Piantanida, David
Sent: Thursday, June 04, 2015 11:44 AM
To: Walsh, Ed
Cc: Blizzard, James
Subject: Fwd: Final- HF Study News Release, 12 PM

Here is the final release.

David Piantanida, 202-564-8318

US EPA

Office of Research and Development

Ex. 6

Sent from my iPhone

Begin forwarded message:

From: "Allen, Laura" <Allen.Laura@epa.gov>
Date: June 4, 2015 at 11:34:11 AM EDT
To: "Daguillard, Robert" <Daguillard.Robert@epa.gov>, AO OPA OMR 60 Minute Warning <AO_OPA_OMR_60_Minute_Warning@epa.gov>
Subject: Final- HF Study News Release, 12 PM

Hi all- the final version of the press release is below and it will be sent at noon today. Thanks!

Laura Allen

Deputy Press Secretary
Office of the Administrator
U.S. Environmental Protection Agency

Email: Allen.Laura@epa.gov

Office: 202-564-1175

Ex. 6

Please consider the environment before printing this email.

Contact: (News Media Only)

Cathy Milbourn

(202) 564-7849

Ex. 6

milbourn.cathy@epa.gov

Ex. 5

Ex. 5

Ex. 5

Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources

Presentation by the
U.S. Environmental Protection Agency
Office of Research and Development

4 June 2015

HF Study Background

- In FY2010, Congress urged EPA to study the relationship between hydraulic fracturing and drinking water.
- EPA launched this study with the purpose to:
  - Assess whether hydraulic fracturing can impact drinking water resources
  - Identify driving factors that affect the severity and frequency of any impacts
- EPA's HF study was outlined in a 2011 *Study Plan* with additional details provided in a 2012 *Progress Report.*

HF Study Progress

- EPA's HF study has produced:
  - 12 EPA technical reports – Including 9 reports being released today
  - 4 EPA authored journal publications
  - 9 journal publications from colleagues at Lawrence Berkeley National Laboratory
  - Draft Hydraulic Fracturing Drinking Water Assessment report
- All completed products available online:
  - www.epa.gov/hfstudy

Final HF Technical Reports Released Today

- Study of water acquisition in the Susquehanna and Upper Colorado river basins.
- Study of sources of selected HF-related chemicals in the Allegheny river and streams in PA.
- Studies of possible impacts to drinking water resources (five retrospective case studies):
    - Northeast, PA (Bradford County)
    - Southwest, PA (Washington County)
    - Killdeer, ND
    - Raton Basin, CO
    - Wise County, TX
- Description of well construction and design characteristics.
- Characterization of spills related to HF operations.

Draft HF Assessment Report

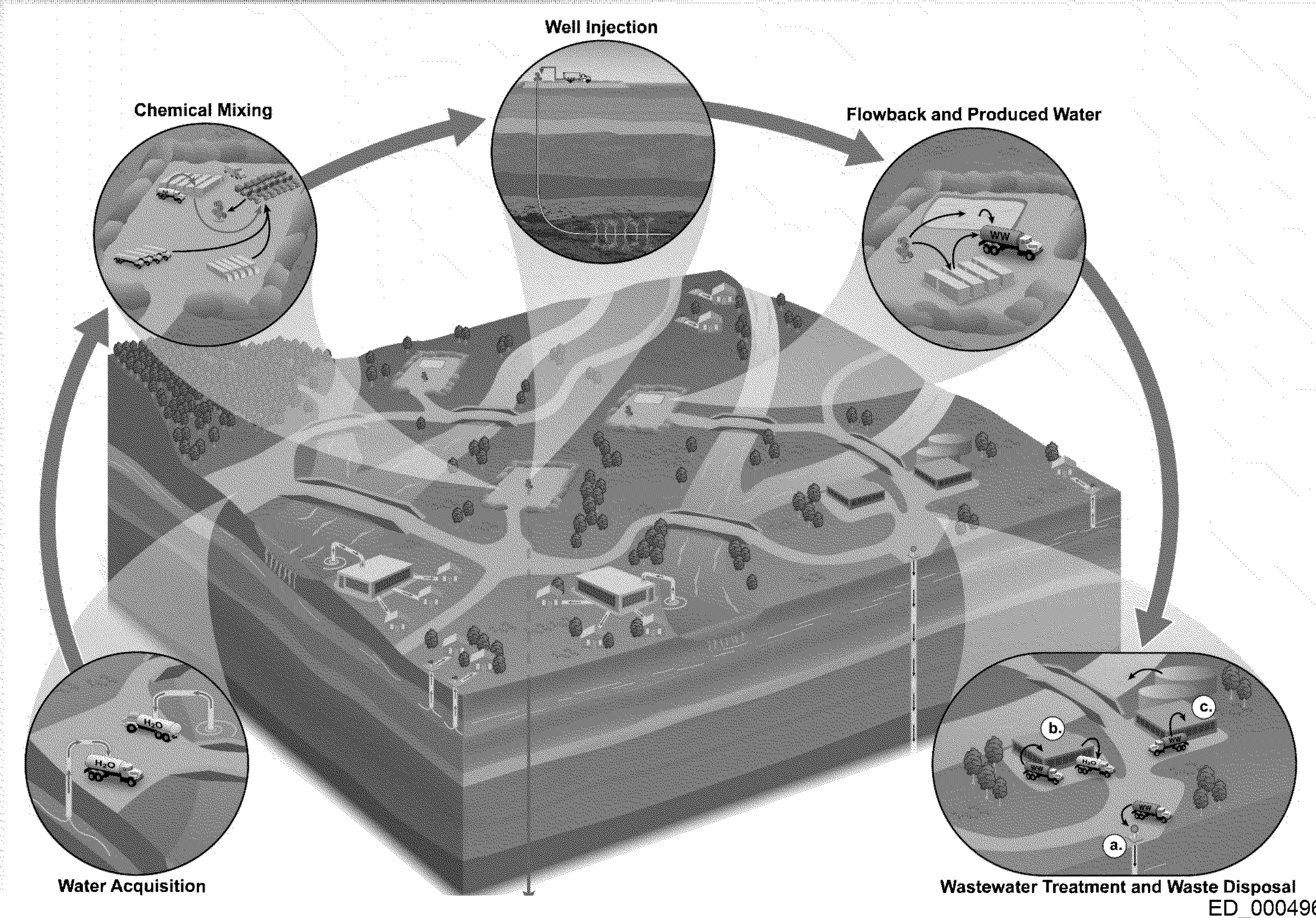
What it is:

- A state-of-the-science integration and synthesis of information
- Based upon EPA research results, a robust literature review, and other information, including input from stakeholders.
- Identifies potential vulnerabilities and addresses questions identified in the *Study Plan* and *Progress Report*

What it is not:

- Not a human health, exposure, or risk assessment
- Not site specific
- Does not identify or evaluate best management practices
- Not designed to inform specific policy decisions
- Does not identify or evaluate policy options

Hydraulic Fracturing Water Cycle: Follow the water



Summary of Impacts on Drinking Water Resources

- Assessment identified potential vulnerabilities to drinking water resources due to hydraulic fracturing activities.
- These vulnerabilities include:
  - Water withdrawals in areas with low water availability
  - Spills of HF fluids and flowback/produced water
  - HF conducted directly into formations containing drinking water resources
  - Well integrity failures
  - Subsurface migration of gases and liquids
  - Inadequately treated wastewater
- Despite vulnerabilities, there is no evidence of widespread, systemic impacts on drinking water resources due to hydraulic fracturing activities.

Water Acquisition: Sources and volume

- Sources of water used for HF include surface water, ground water, and reused wastewaters.
- Cumulative water use is at least 42 BG/year; Median water use for a well is approximately 1.5 MG.
- There is much variability and water use varies between <1 MG to >5 MG per well.
- Factors affecting water use include:
    - length of well (well volume)
    - formation depth and geology
    - fracturing fluid formulation

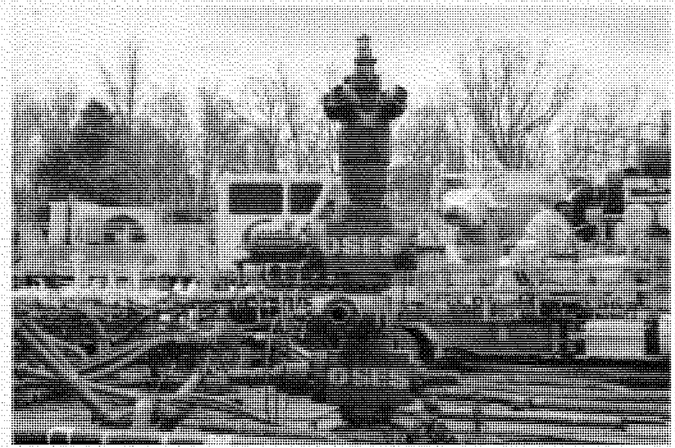
Water Acquisition: Comparison to other uses

- HF water use is small compared with total water use and consumption at the national and state spatial scales.
- For most counties, HF activities account for <1% of total water use and consumption.
    - In 6% of counties HF activities account for >10% total water use
- Potential for impacts on drinking water resources greatest in areas with:
    - High HF water use
    - Low water availability
    - Frequent drought
    - Declining water sources
- Example area experiencing all four factors: southern and western Texas.

Chemical Mixing

Chemical Mixing: HF Fluids

- HF fluids generally consist of:
  - Base fluid
  - Chemical additives
  - Proppants



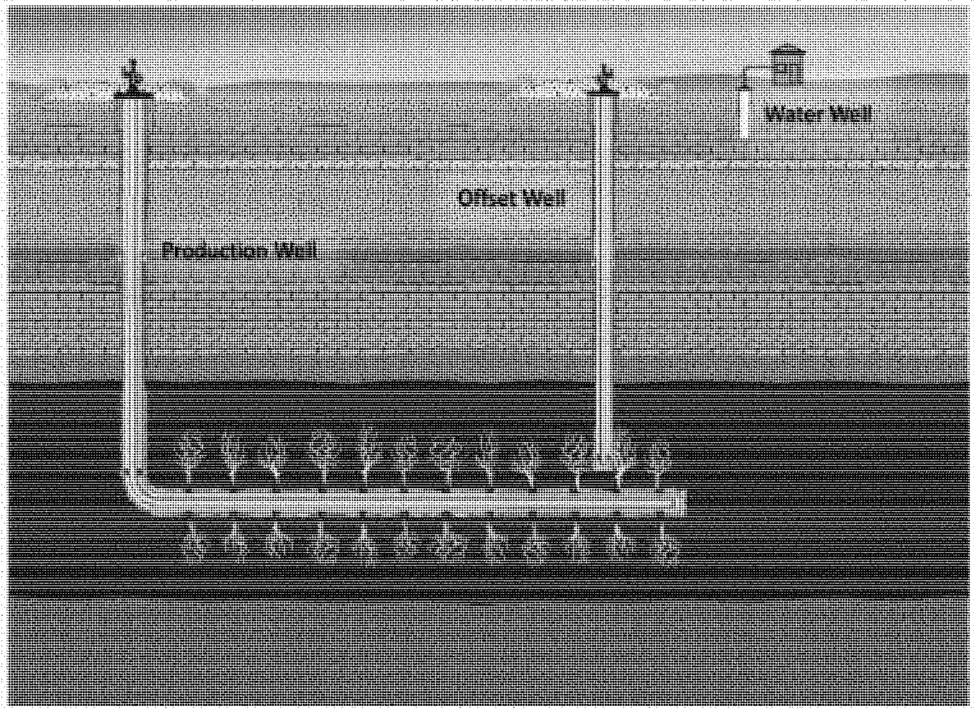
- Base fluids:
  - Largest constituent by volume
  - Most often water
  - Other base fluids include: non-aqueous fluids, acids, energized fluids, foams and emulsions
- Proppants:
  - Most often sands, resin-coated sands, other specialty engineered particles

Chemical Mixing: HF Chemical Additives

- Chemical additives:
  - Perform multiple functions
  - Can be a single chemical or a mixture of multiple chemicals
  - Are injected during different stages of the HF process
  - Generally comprise <2% of injected fluid volumes
  - Thousands of gallons are potentially stored on-site and used in the HF process
- We identified more than 1000 chemicals used as components of HF fluids:
  - Median of 14 unique chemicals used per well
  - No single chemical used at all well sites across country
  - Chemicals used at >65% of well sites include: methanol, hydrotreated light petroleum distillates, hydrochloric acid

Well Injection: Potential subsurface pathways

- Movement of gas or fluids from the wellbore into a drinking water resource
- Movement of gas or fluids from production zone through subsurface rock formations into a drinking water resource



Well Construction and Integrity

- Multiple barriers act together to prevent migration of gases and fluids.
- Inadequate construction, defects and degradation of casings or cement, or absence of redundancies can create pathways leading to contamination of drinking water resources.
- EPA's Well File Review Report:
  - Estimated 66% of wells had one or more uncemented intervals
  - Estimated 3% of wells did not have cement across the entire drinking water resource
- Specific rate of well failures unknown but generally increases over time.

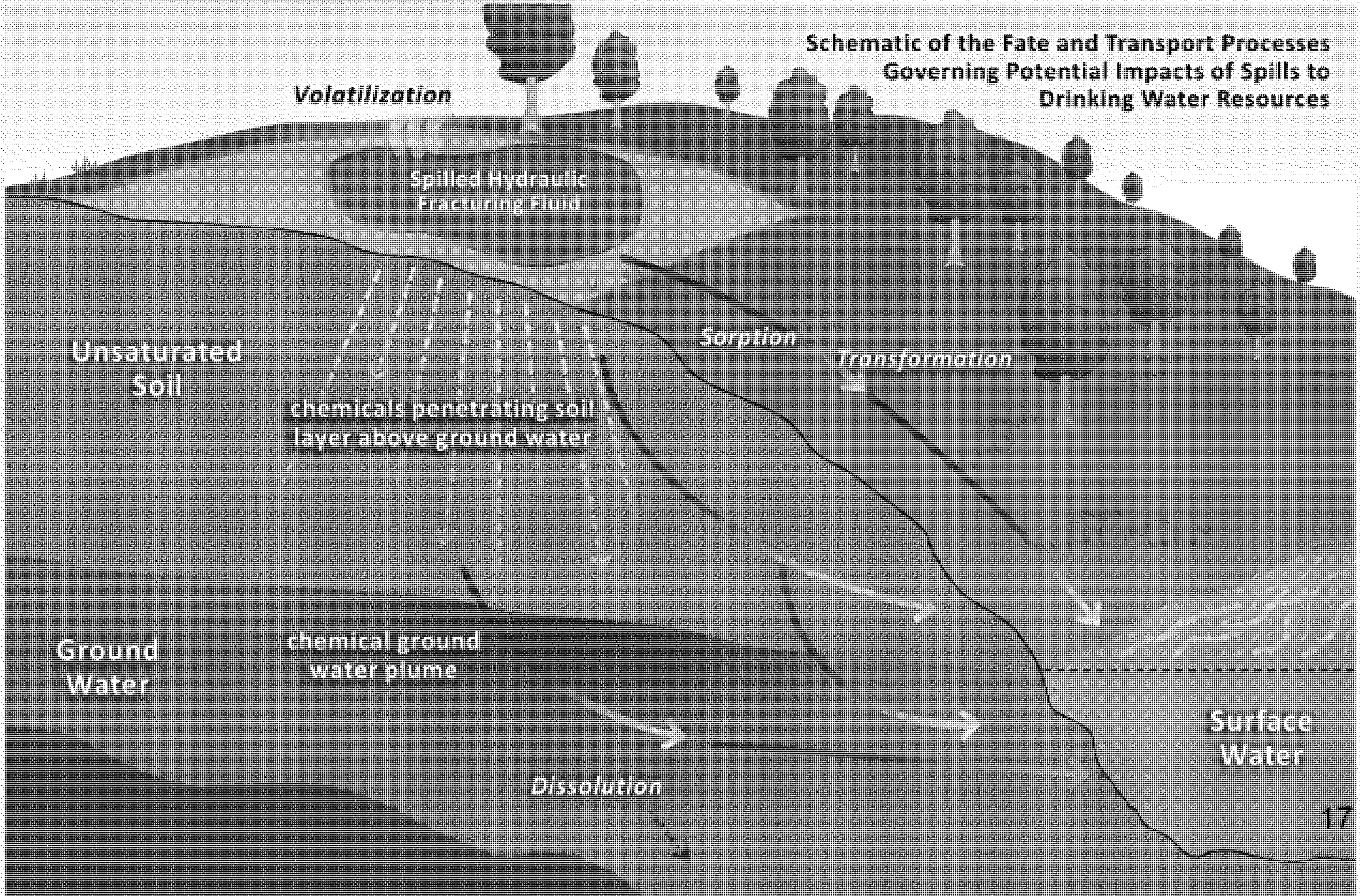
Sub-Surface Movement

- Physical separation between the production zone and drinking water resources can minimize impacts.
- In some cases, the production zone is co-located with drinking water resources:
    - Estimated 0.4% of wells fractured in 2009 and 2010 showed evidence of fracturing directly within a drinking water resource
    - Use of the drinking water resource not well characterized
- Deep HF operations are unlikely to create direct flow paths from fracture production zones to shallow drinking water resources.
- Well-to-well communications provide documented and potential pathways for fluid movement into drinking water resources.

Flowback and Produced Water

- Flowback and produced water come out of the well when pressure is released.
- Amount of fracturing fluid returned to surface is generally 10% to 25% of injected fluid and varies widely.
- Data on produced water composition limited:
  - 134 chemical detected specifically in FB/PW
  - High total disolved solids
  - Metals, organics
  - Naturally occurring radionuclides
- High TDS present analytical challenges for characterizing chemical composition

Chemical Mixing: Spills



Spills of HF Fluids and Produced Waters

- Spills of HF fluids and produced waters have occurred; when spills occur, they can and have reached drinking water resources through multiple pathways.
- Total number and frequency of spills due to HF activities unknown.
- Based upon spill data reviewed:
    - Hundreds of spills of hydraulic fracturing fluids and produced waters have occurred
    - Spill volumes varied greatly: 2 gallons to 1.3 Million gallons
    - Most common causes of spills were equipment failure and human error
    - Of those spills reviewed, 8% of documented spills reached a surface or ground water resource; 64% reached soils

Hydraulic Fracturing Wastewater

- HF produces large volumes of wastewater.
- Most HF wastewater is disposed of using underground injection control (UIC) wells.
- UIC disposal varies geographically:
  - 95% UIC in Barnett Shale area (TX)
  - 10% UIC in Marcellus Shale area (PA)
- Wastewater reuse varies geographically:
  - 5% wastewater use in Barnett Shale area
  - 70% wastewater reuse in Marcellus Shale area
- Other disposal options for HF wastewater:
  - Commercial wastewater treatment facilities (CWT)
  - Evaporation pits, land irrigation and road spreading

HF Chemical Characterization

- 1,173 chemicals reportedly used in HF fluids or detected in FB/PW.
- 148 have human oral toxicity reference values.
- Absence of toxicity reference values limits ability to conduct future site specific exposure/risk assessments.
- CBI limits complete characterization of chemical use in HF operations:
  - From EPA's analysis of the FracFocus 1.0 database
  - One or more ingredients were claimed as confidential in more than 70% of disclosures
  - Operators designated 11% of all ingredient records as confidential business information

Conclusions

- Assessment identified potential vulnerabilities to drinking water resources due to hydraulic fracturing activities.
- The number of documented impacts to drinking water resources is small relative to the number of fractured wells.
- Despite vulnerabilities, there is no evidence of widespread, systemic impacts on drinking water resources due to hydraulic fracturing activities.

Use of Assessment

- EPA's assessment represents a synthesis of the science and contributes to overall understanding of potential impacts.
- The assessment helps to advance the science and understanding of hydraulic fracturing by identifying potential vulnerabilities.
- The assessment can inform future decisions by industry and by federal, tribal, state, and local entities concerning how best to protect drinking water resources now and in the future.

What's Next

- Science Advisory Board (SAB) review of draft assessment:
    - Public, open process
    - Opportunity to comment on charge questions
    - Opportunity to address SAB panel concerning EPA's draft assessment
    - Opportunity to provide comments on the draft assessment
- Agency will use comments from public and SAB to revise draft assessment and release as final.

To: Maloney, Kelsey[Maloney.Kelsey@epa.gov]
From: Gibbons, Dayna
Sent: Thur 3/12/2015 2:48:23 PM
Subject: FW: Please Review Weekly Report, ORD, March 13 - March 22, 2015

Ex. 5

From: D'Amico, Louis
Sent: Wednesday, March 11, 2015 5:57 PM
To: Gibbons, Dayna; Shams, Dahnish
Subject: RE: Please Review Weekly Report, ORD, March 13 - March 22, 2015

Hi Dayna,

Ex. 5

-Lou

Louis D'Amico, Ph.D.

Acting Communications Director, ORD/NCEA

damico.louis@epa.gov

O: (703) 347-0344 M: Ex. 6

From: Gibbons, Dayna
Sent: Tuesday, March 10, 2015 9:59 AM
To: D'Amico, Louis; Shams, Dahnish
Subject: RE: Please Review Weekly Report, ORD, March 13 - March 22, 2015

Ex. 5

From: D'Amico, Louis
Sent: Monday, March 09, 2015 11:18 AM
To: Gibbons, Dayna
Subject: Automatic reply: Please Review Weekly Report, ORD, March 13 - March 22, 2015

Ex. 6 If you need immediate attention, please contact me on my mobile at Ex. 6 I will respond to your message as soon as possible on my return to the office.

To: Maloney, Kelsey[Maloney.Kelsey@epa.gov]
From: Gibbons, Dayna
Sent: Thur 3/12/2015 2:48:15 PM
Subject: FW: Please Review Weekly Report, ORD, March 13 - March 22, 2015

Ex. 5

From: D'Amico, Louis
Sent: Wednesday, March 11, 2015 6:01 PM
To: Gibbons, Dayna; Shams, Dahnish
Subject: RE: Please Review Weekly Report, ORD, March 13 - March 22, 2015

Hi all,

Apologies, some edits didn't save to the fact sheet. Here's the current version, renamed with today's date and "pm"

Louis D'Amico, Ph.D.

Acting Communications Director, ORD/NCEA

damico.louis@epa.gov

O: (703) 347-0344 M: (703) 859-1719

From: D'Amico, Louis
Sent: Wednesday, March 11, 2015 5:57 PM
To: Gibbons, Dayna; Shams, Dahnish
Subject: RE: Please Review Weekly Report, ORD, March 13 - March 22, 2015

Hi Dayna,

Ex. 5

-Lou

Louis D'Amico, Ph.D.

Acting Communications Director, ORD/NCEA

damico.louis@epa.gov

O: (703) 347-0344 M: Ex. 6

From: Gibbons, Dayna
Sent: Tuesday, March 10, 2015 9:59 AM
To: D'Amico, Louis; Shams, Dahnish
Subject: RE: Please Review Weekly Report, ORD, March 13 - March 22, 2015

Ex. 5

From: D'Amico, Louis
Sent: Monday, March 09, 2015 11:18 AM
To: Gibbons, Dayna
Subject: Automatic reply: Please Review Weekly Report, ORD, March 13 - March 22, 2015

Ex. 6 I will be checking email intermittently during this time. If you need immediate attention, please contact me on my mobile at Ex. 6 will respond to your message as soon as possible on my return to the office.

To: Perry, Dale[Perry.Dale@epa.gov]
From: Gibbons, Dayna
Sent: Fri 3/6/2015 5:07:28 PM
Subject: FW: Please Expedite - HF paper for review: surface water modeling

Ex. 5

Ex. 5

From: Maloney, Kelsey
Sent: Wednesday, March 04, 2015 11:02 AM
To: Gibbons, Dayna
Subject: RE: Please Expedite - HF paper for review: surface water modeling

Ex. 5

From: Gibbons, Dayna
Sent: Wednesday, March 04, 2015 10:55 AM
To: Maloney, Kelsey
Subject: FW: Please Expedite - HF paper for review: surface water modeling
Importance: High

Ex. 5

From: Matthews, Lisa
Sent: Wednesday, March 04, 2015 10:49 AM
To: Smith, Kelley
Cc: Kavlock, Robert; Teichman, Kevin; Zambrana, Jose; Gibbons, Dayna; Bueno, Michael
Subject: Please Expedite - HF paper for review: surface water modeling
Importance: High

Ex. 5

Lisa

From: Smith, Kelly
Sent: Wednesday, March 04, 2015 8:00 AM
To: Zambrana, Jose; Matthews, Lisa
Cc: Sonich-Mullin, Cynthia; Bueno, Michael
Subject: RE: Draft Deliberative -SW paper

Hello Lisa,

Ex. 5

Ex. 5

Thanks

From: Zambrana, Jose
Sent: Tuesday, March 03, 2015 7:21 PM
To: Smith, Kelly; Matthews, Lisa
Cc: Sonich-Mullin, Cynthia; Bueno, Michael
Subject: RE: Draft Deliberative -SW paper

Ex. 5

Jose

To: Teichman, Kevin[Teichman.Kevin@epa.gov]
From: Gibbons, Dayna
Sent: Thur 2/26/2015 11:18:06 PM
Subject: Fwd: a few follow up questions re the HF water study

Ex. 5

Sent from my iPhone

Begin forwarded message:

> **From:** "Purchia, Liz" <Purchia.Liz@epa.gov>
> **Date:** February 26, 2015 at 6:11:43 PM EST
> **To:** "Gibbons, Dayna" <Gibbons.Dayna@epa.gov>, "Hubbard, Carolyn" <Hubbard.Carolyn@epa.gov>
> **Cc:** "Perry, Dale" <Perry.Dale@epa.gov>, "Hanley, Mary" <Hanley.Mary@epa.gov>, "Allen, Laura" <Allen.Laura@epa.gov>
> **Subject: RE: a few follow up questions re the HF water study**

Ex. 5

Ex. 5

Ex. 5

Liz Purchia

Press Secretary

U.S. Environmental Protection Agency

Direct: 202-564-6691

Cell: 202-841-2230

From: Gibbons, Dayna
Sent: Wednesday, February 25, 2015 3:54 PM
To: Purchia, Liz; Hubbard, Carolyn
Cc: Perry, Dale; Hanley, Mary; Allen, Laura
Subject: RE: a few follow up questions re the HF water study

Ex. 5

From: Purchia, Liz
Sent: Wednesday, February 25, 2015 2:06 PM
To: Hubbard, Carolyn; Gibbons, Dayna
Cc: Perry, Dale; Hanley, Mary; Allen, Laura
Subject: FW: a few follow up questions re the HF water study

Do you wa Ex. 5

Liz Purchia

Press Secretary

U.S. Environmental Protection Agency

Direct: 202-564-6691

Ex. 6

From: Neela Banerjee [mailto:neela.banerjee@insideclimatenews.org]
Sent: Wednesday, February 25, 2015 11:52 AM
To: Purchia, Liz
Subject: a few follow up questions re the HF water study

Hey, Liz,

Ex. 5

Ex. 5

Allbest

Neela

--

Neela Banerjee

neela.banerjee@insideclimatenews.org
202-297-9915

follow me on Twitter @neelaeast

To: Gibbons, Dayna[Gibbons.Dayna@epa.gov]
Cc: Maloney, Kelsey[Maloney.Kelsey@epa.gov]
From: Chagolla, Armando
Sent: Tue 6/2/2015 9:49:08 PM
Subject: RE: Please review asap for accuracy.

Ex. 5

Ex. 5

From: Gibbons, Dayna
Sent: Tuesday, June 02, 2015 10:54 AM
To: Chagolla, Armando
Cc: Maloney, Kelsey
Subject: FW: Please review asap for accuracy.

Ex. 5

From: Briskin, Jeanne
Sent: Tuesday, June 02, 2015 8:10 AM
To: Gibbons, Dayna; Matthews, Lisa; Frithsen, Jeff
Subject: RE: Please review asap for accuracy.

From: Gibbons, Dayna
Sent: Monday, June 01, 2015 4:54 PM
To: Matthews, Lisa; Frithsen, Jeff; Briskin, Jeanne
Subject: Please review asap for accuracy.

Ex. 5

To: Gibbons, Dayna[Gibbons.Dayna@epa.gov]
Cc: Gwinn, Maureen[gwinn.maureen@epa.gov]; Bueno, Michael[Bueno.Michael@epa.gov]; Kavlock, Robert[Kavlock.Robert@epa.gov]; Matthews, Lisa[Matthews.Lisa@epa.gov]
From: Frithsen, Jeff
Sent: Tue 6/9/2015 9:34:05 PM
Subject: Re: Technical Roundtable on Draft HFDWA meeting this week

Ex. 5

Jeff

Sent from Jeff Frithsen's iPhone
Office phone: 703-347-8623

Ex. 6

On Jun 9, 2015, at 5:01 PM, Gibbons, Dayna <Gibbons.Dayna@epa.gov> wrote:

Ex. 5

Ex. 5

From: Gwinn, Maureen
Sent: Tuesday, June 09, 2015 4:59 PM
To: Bueno, Michael; Kavlock, Robert
Cc: Matthews, Lisa; Gibbons, Dayna; Frithsen, Jeff
Subject: RE: Technical Roundtable on Draft HFDWA meeting this week

Ex. 5

Maureen R. Gwinn, PhD DABT ATS

Special Assistant/IOAA

t(202)564-4621

Ex. 6

From: Bueno, Michael
Sent: Tuesday, June 09, 2015 3:56 PM
To: Gwinn, Maureen; Kavlock, Robert
Cc: Matthews, Lisa; Gibbons, Dayna; Frithsen, Jeff
Subject: RE: Technical Roundtable on Draft HFDWA meeting this week

Hi Bob and Maureen,

Attached are the introductory remarks we've prepared for tomorrow's webinar. Please let us know if you would like any changes.

Thank you,

Michael

Michael Bueno

US EPA Office of Research and Development

p. (202) 564-5051

e. bueno.michael@epa.gov

From: Matthews, Lisa
Sent: Monday, June 08, 2015 6:27 PM
To: Gwinn, Maureen
Cc: Frithsen, Jeff; Gibbons, Dayna; Bueno, Michael
Subject: Re: Technical Roundtable on Draft HFDWA meeting this week

We'll get you a brief script, intro remarks on Wed am. Michael, please make sure Hurd Hall is reserved. Thanks.

Sent from my iPhone

On Jun 8, 2015, at 10:51 AM, Gwinn, Maureen <gwinn.maureen@epa.gov> wrote:

Hi Jeff –

Ex. 5

Thanks,

Maureen

Maureen R. Gwinn, PhD DABT ATS

Special Assistant

Immediate Office of the Assistant Administrator

Office of Research and Development
1200 Pennsylvania Ave NW

MC 8101R
Washington, DC 20460

t(202)564-4621

f(202)565-2430

Ex. 6

To: Kenny, Joan[jkenny@usgs.gov]
From: LeDuc, Stephen
Sent: Thur 3/12/2015 11:52:55 AM
Subject: Question about hydraulic fracturing water use and water census

Hi Joan,

Ex. 5

Best,

Steve

Stephen D. LeDuc, PhD

US Environmental Protection Agency

National Center for Environmental Assessment, Arlington, VA 22202

Office Phone: (703) 347-8962; Ex. 6

Non-Responsive

Non-Responsive

Non-Responsive

Non-Responsive

Non-Responsive

To: Maloney, Kelsey[Maloney.Kelsey@epa.gov]
From: John Christie
Sent: Thur 6/25/2015 6:50:14 PM
Subject: Re: Form submission from: EPA's Study of Hydraulic Fracturing and Its Potential Impact on Drinking Water Resources Contact Us about EPA's Hydraulic Fracturing Study form

Kelsey,

Ex. 5

Thank you
John

John M. Christie BME, MBA
VTC Vineyard Technology Consulting
Ex. 4
Website: www.vineyardtechconsulting.com

From: "Maloney, Kelsey" <Maloney.Kelsey@epa.gov>
To: "jchristie **Ex. 4**
Sent: Thursday, June 25, 2015 6:32 AM
Subject: Form submission from: EPA's Study of Hydraulic Fracturing and Its Potential Impact on Drinking Water Resources Contact Us about EPA's Hydraulic Fracturing Study form

Thank you for your email and interest in EPA's Study of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources. The draft assessment addresses potential impacts to drinking water resources at each stage of the hydraulic fracturing water cycle: water acquisition, chemical mixing, well injection, flowback and produced water, and wastewater treatment and disposal. This is a state-of-the-science assessment. Air quality, including air emissions, is outside the study's scope.

-----Original Message-----
From: drupal_admin@epa.gov [mailto:drupal_admin@epa.gov]
Sent: Wednesday, June 10, 2015 4:39 PM
To: Maloney, Kelsey
Subject: Form submission from: EPA's Study of Hydraulic Fracturing and Its Potential Impact on Drinking Water Resources Contact Us about EPA's Hydraulic Fracturing Study form

Submitted on 06/10/2015 4:38PM
Submitted values are:

Name: John Christie

Email: Ex. 4
Comments: Can you provide any studies on ghg emissions from fracking; including flaring and venting during the flow back period.
Web Area: EPA's Study of Hydraulic Fracturing and Its Potential Impact on Drinking Water Resources

To: Allen, Laura[Allen.Laura@epa.gov]
Cc: Gibbons, Dayna[Gibbons.Dayna@epa.gov]; Purchia, Liz[Purchia.Liz@epa.gov]; Hubbard, Carolyn[Hubbard.Carolyn@epa.gov]; Maguire, Megan[Maguire.Megan@epa.gov]; Valentine, Julia[Valentine.Julia@epa.gov]; Maloney, Kelsey[Maloney.Kelsey@epa.gov]; Hull, George[Hull.George@epa.gov]; Lehman, Rachel[Lehman.Rachel@epa.gov]; Perry, Dale[Perry.Dale@epa.gov]
From: Milbourn, Cathy
Sent: Mon 6/8/2015 9:53:31 PM
Subject: Re: Press Request-- please respond

Ex. 5

Sent from my iPhone

On Jun 8, 2015, at 3:52 PM, "Allen, Laura" <Allen.Laura@epa.gov> wrote:

Ex. 5

Ex. 5

Ex. 5

Ex. 5

From: Gibbons, Dayna
Sent: Monday, June 08, 2015 2:55 PM
To: Milbourn, Cathy; Purchia, Liz
Cc: Hubbard, Carolyn; Maguire, Megan; Valentine, Julia; Allen, Laura; Maloney, Kelsey; Hull, George; Lehman, Rachel; Perry, Dale
Subject: Press Request-- please respond

Ex. 5

To: Reynolds, Thomas[Reynolds.Thomas@epa.gov]; Purchia, Liz[Purchia.Liz@epa.gov]
From: Allen, Laura
Sent: Thur 6/4/2015 3:20:18 PM
Subject: HF release- updated

Ex. 5

Attached.

To: Ridley, Caroline[Ridley.Caroline@epa.gov]
Cc: Soto, Vicki[Soto.Vicki@epa.gov]; Itkin, Cheryl[Itkin.Cheryl@epa.gov]
From: Konoza, Terri
Sent: Wed 4/8/2015 2:10:24 PM
Subject: FW: Permission to use photos from a JPT article

Hi Caroline,

Ex. 5

Terri

From: Mark Windle Ex. 6
Sent: Wednesday, April 08, 2015 9:57 AM
To: Konoza, Terri
Cc: Christina Colalillo
Subject: RE: Permission to use photos from a JPT article

Good morning Terri,

Thank you for reaching out and checking with us on the matter. We are going to pass on providing permission for the use of this image. I wish you all the best on the report.

Mark Windle

Manager of Corporate Communications

Office: (724) 873-3223

Ex. 6

-

Range Resources Corporation

3000 Town Center Blvd.

Canonsburg, PA 15317

rangeresources.com

From: Konoza, Terri
Sent: Thursday, April 02, 2015 11:42 AM
To: Ex. 6
Subject: Permission to use photos from a JPT article

Good morning,

Ex. 5

Regards,

Terri Konoza

Information Management Specialist

U.S. EPA (8601P)

1200 Pennsylvania Ave., NW

Washington DC 20460

703-347-8672

To: Jonathan.Koplos Ex. 4 John Stanek Ex. 6
Cc: Ridley, Caroline[Ridley.Caroline@epa.gov]; Yost, Erin[Yost.Erin@epa.gov]
From: Stanek, John
Sent: Fri 2/27/2015 5:57:37 PM
Subject: RE: Chapter 9 - clean copy
HFDWA - Chapter 9_Final to Cadmus_022615.docx

Hi Jonathan,

Ex. 5

John

From: Jonathan Koplos Ex. 4
Sent: Thursday, February 26, 2015 4:44 PM
To: John Stanek
Cc: Stanek, John; Ridley, Caroline
Subject: RE: Chapter 9

Really anytime Friday would work.

Ex. 5

Thanks, John.

Jonathan

From: John Stanek Ex. 6
Sent: Thursday, February 26, 2015 4:42 PM
To: Jonathan Koplos
Cc: stanek.john@epa.gov; Caroline Ridley
Subject: RE: Chapter 9

Might be able to do something...if nothing by first thing Fri. Proceed

On Feb 26, 2015 4:33 PM, "Jonathan Koplos" Ex. 4 wrote:

> Hard to accept tracked-changes using candle power!
>
> **From:** John Stanek Ex. 6
> **Sent:** Thursday, February 26, 2015 4:32 PM
> **To:** Ridley, Caroline
> **Cc:** Jonathan Koplos; stanek.john@epa.gov
> **Subject:** Re: Chapter 9
>
> Yeah probably not going to be able to anything until after this review round.....might have power sometime tomorrow
>
> On Feb 26, 2015 4:30 PM, "Ridley, Caroline" <Ridley.Caroline@epa.gov> wrote:
>
>> Jonathan,
>>
>> John's instruction was simply to clear the comments out of the version of chapter 9 that you sent on Monday and put it in the clearance draft. If he can, he will try to address comments from the author team tomorrow, but use the version you have for now.
>>
>> Caroline
>>
>> ~~~~~~
>>
>> Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): Ex. 6

To: Ridley, Caroline[Ridley.Caroline@epa.gov]
Cc: Frithsen, Jeff[Frithsen.Jeff@epa.gov]
From: Yohannes, Lia
Sent: Thur 2/26/2015 8:56:39 PM
Subject: FW: HFDWA: Preliminary External Review Draft, 2/23/2015 - Part 2

Hi Caroline,

Ex. 5

Thanks,

Lia

Liabeth Yohannes

Student Services Contractor

Office of Research and Development

U.S. Environmental Protection Agency

e: Yohannes.lia@epa.gov

p: 202.564.6755

From: Briskin, Jeanne
Sent: Thursday, February 26, 2015 3:49 PM
To: Yohannes, Lia; Ridley, Caroline
Cc: Frithsen, Jeff; Hauchman, Fred
Subject: Fwd: HFDWA: Preliminary External Review Draft, 2/23/2015 - Part 2

Hi

Ex. 5

Ex. 5

Begin forwarded message:

From: "Briskin, Jeanne" <Briskin.Jeanne@epa.gov>
Date: February 26, 2015 at 12:18:53 AM EST
To: "Ridley, Caroline" <Ridley.Caroline@epa.gov>, "Yohannes, Lia" <Yohannes.Lia@epa.gov>, "Fleming, Megan" <Fleming.Megan@epa.gov>, "Knightes, Chris" <Knightes.Chris@epa.gov>, Ex. 4 Ex. 4 "Weaver, Jim" <Weaver.Jim@epa.gov>, Ex. 4 "Stanek, John" <Stanek.John@epa.gov>, "LeDuc, Stephen" <LeDuc.Stephen@epa.gov>
Cc: "Frithsen, Jeff" <Frithsen.Jeff@epa.gov>
Subject: Re: HFDWA: Preliminary External Review Draft, 2/23/2015 - Part 2

It's impressive and wonderful to see the assessment assembled. I am reading it from the beginning and will provide detailed comments as I finish each chapter. But to honor Jeff's request for feedback on just 2 days here are several concerning issues I have spotted in an overall skim of the document. Because Jeff really asked for a focus on bigger issues, unfortunately the list below does not properly acknowledge all the things the draft does right. I'm happy to discuss the concerns listed with you. Thanks for the opportunity to weigh in.

Ex. 5

Ex. 5

Thanks!
Jeanne

On Feb 25, 2015, at 2:59 PM, Frithsen, Jeff <Frithsen.Jeff@epa.gov> wrote:

Sending Part B again. May not have been sent correctly. Or received correctly.

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Frithsen, Jeff

Sent: Monday, February 23, 2015 9:57 PM

To: Teichman, Kevin; Briskin, Jeanne; Matthews, Lisa; Gibbons, Dayna; Zambrana, Jose

Subject: FW: HFDWA: Preliminary External Review Draft, 2/23/2015 - Part 2

More sharing……

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Frithsen, Jeff

Sent: Monday, February 23, 2015 9:52 PM

To: 'Anna Weber'; Bates, William; 'Brent Ranalli'; Burden, Susan; Burgoon, Lyle; Clark, Christopher; Cluff, Maryam; Daiss, Rebecca; Dean, Jill; 'Deniz (Inci) Demirkanli'; Fleming, Megan; 'Glen Boyd
Ex. 4
Impellitteri, Christopher; 'Jonathan Koplos'; 'Ken Klewicki
Ex. 4 ;

Knightes, Chris; LeDuc, Stephen; 'Mary Ellen Tuccillo'; Ridley, Caroline; 'Sandie Koenig'; Shari.Ring Ex. 4 ; Singer, Alison; Stanek, John; Todd, Jason; Weaver, Jim; Williams, Larke; Yohannes, Lia; Yost, Erin

Subject: RE: HFDWA: Preliminary External Review Draft, 2/23/2015 - Part 2

HFDWA Preliminary External Review Draft, 2/23/2015 – Part 2 – Chapters 5 through 10.

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Frithsen, Jeff

Sent: Monday, February 23, 2015 9:48 PM

To: 'Anna Weber'; Bates, William; 'Brent Ranalli'; Burden, Susan; Burgoon, Lyle; Clark, Christopher; Cluff, Maryam; Daiss, Rebecca; Dean, Jill; 'Deniz (Inci) Demirkanli'; Fleming, Megan; Frithsen, Jeff; 'Glen Boyd (Ex. 4 Impellitteri, Christopher; 'Jonathan Koplos'; 'Ken Klewicki (Ex. 4)'; Knightes, Chris; LeDuc, Stephen; 'Mary Ellen Tuccillo'; Ridley, Caroline; 'Sandie Koenig'; Shari.Ring Ex. 4 ; Singer, Alison; Stanek, John; Todd, Jason; Weaver, Jim; Williams, Larke; Yohannes, Lia; Yost, Erin

Subject: HFDWA: Preliminary External Review Draft, 2/23/2015 - Part 1

Team:

Ex. 5

Ex. 5

Ex. 5

Jeff

Jeffrey B. Frithsen, Ph.D.

National Center for Environmental Assessment

Office of Research and Development

U.S. Environmental Protection Agency

1200 Pennsylvania Avenue, SW (8623-P)

Washington, DC 20460

703-347-8623 (office phone)

Physical Office Address/Overnight Deliveries

Two Potomac Yard (North Building), Room N-7741

2733 South Crystal Drive, Arlington, VA 22202

Ex. 5

To: Ridley, Caroline[Ridley.Caroline@epa.gov]; Frithsen, Jeff[Frithsen.Jeff@epa.gov]; Jonathan.Koplo Ex. 4
Cc: Anna Weber Ex. 4 Deniz (Inci) Demirkanli Ex. 4 ; Ken Klewicki Ex. 4
From: Shari Ring
Sent: Thur 2/26/2015 8:48:50 PM
Subject: Chapter 6
Chapter 6 - February 2015.docx

Attached is an updated Chapter 6. Ex. 5
Ex. 5

Ex. 5

Shari Ring

The Cadmus Group, Inc.

Ex. 4

Follow us on social media:

To: Ridley, Caroline[Ridley.Caroline@epa.gov]
From: Shari Ring
Sent: Thur 2/26/2015 5:12:14 PM
Subject: FW: HFDWA: Preliminary External Review Draft, 2/23/2015 - Part 2

Ex. 5

Shari Ring
The Cadmus Group, Inc.
Ex. 4

-----Original Message-----
From: Briskin, Jeanne [mailto:Briskin.Jeanne@epa.gov]
Sent: Thursday, February 26, 2015 12:19 AM
To: Ridley, Caroline; Yohannes, Lia; Fleming, Megan; Knightes, Chris; Shari Ring; Weaver, Jim; Mary Ellen Tuccillo; Stanek, John; LeDuc, Stephen
Cc: Frithsen, Jeff
Subject: Re: HFDWA: Preliminary External Review Draft, 2/23/2015 - Part 2

Ex. 5

Jeanne

Ex. 5

Ex. 5

Thanks!
Jeanne

> On Feb 25, 2015, at 2:59 PM, Frithsen, Jeff <Frithsen.Jeff@epa.gov> wrote:
>
> Sending Part B again.   May not have been sent correctly. Or received correctly.
>
> Jeff Frithsen
> USEPA-ORD-NCEA
> 703-347-8623 (office phone)
>
> From: Frithsen, Jeff
> Sent: Monday, February 23, 2015 9:57 PM
> To: Teichman, Kevin; Briskin, Jeanne; Matthews, Lisa; Gibbons, Dayna;
> Zambrana, Jose
> Subject: FW: HFDWA: Preliminary External Review Draft, 2/23/2015 -

> Part 2
>
> More sharing......
>
> Jeff Frithsen
> USEPA-ORD-NCEA
> 703-347-8623 (office phone)
>
> From: Frithsen, Jeff
> Sent: Monday, February 23, 2015 9:52 PM
> To: 'Anna Weber'; Bates, William; 'Brent Ranalli'; Burden, Susan;
> Burgoon, Lyle; Clark, Christopher; Cluff, Maryam; Daiss, Rebecca;
> Dean, Jill; 'Deniz (Inci) Demirkanli'; Fleming, Megan; 'Glen Boyd
> Ex. 4;
> Impellitteri, Christopher; 'Jonathan Koplos'; 'Ken Klewicki
> Ex. 4
> Knightes, Chris; LeDuc, Stephen; 'Mary Ellen Tuccillo'; Ridley,
> Caroline; 'Sandie Koenig';
> Shari.Ring Ex. 4 Singer,
> Alison; Stanek, John; Todd, Jason; Weaver, Jim; Williams, Larke;
> Yohannes, Lia; Yost, Erin
> Subject: RE: HFDWA: Preliminary External Review Draft, 2/23/2015 -
> Part 2
>
> HFDWA Preliminary External Review Draft, 2/23/2015 - Part 2 - Chapters 5 through 10.
>
>
>
> Jeff Frithsen
> USEPA-ORD-NCEA
> 703-347-8623 (office phone)
>
> From: Frithsen, Jeff
> Sent: Monday, February 23, 2015 9:48 PM
> To: 'Anna Weber'; Bates, William; 'Brent Ranalli'; Burden, Susan;
> Burgoon, Lyle; Clark, Christopher; Cluff, Maryam; Daiss, Rebecca;
> Dean, Jill; 'Deniz (Inci) Demirkanli'; Fleming, Megan; Frithsen, Jeff;
> 'Glen Boyd
> Ex. 4
> Impellitteri, Christopher; 'Jonathan Koplos'; 'Ken Klewicki
> Ex. 4;
> Knightes, Chris; LeDuc, Stephen; 'Mary Ellen Tuccillo'; Ridley,
> Caroline; 'Sandie Koenig';
> Shari.Ring Ex. 4; Singer,
> Alison; Stanek, John; Todd, Jason; Weaver, Jim; Williams, Larke;
> Yohannes, Lia; Yost, Erin
> Subject: HFDWA: Preliminary External Review Draft, 2/23/2015 - Part 1
>
> Team:
>

Ex. 5

Ex. 5

>
> Jeff
>

> Jeffrey B. Frithsen, Ph.D.
> National Center for Environmental Assessment Office of Research and
> Development U.S. Environmental Protection Agency
> 1200 Pennsylvania Avenue, SW (8623-P)
> Washington, DC 20460
> 703-347-8623 (office phone)
>
> Physical Office Address/Overnight Deliveries Two Potomac Yard (North
> Building), Room N-7741
> 2733 South Crystal Drive, Arlington, VA 22202
>
> **Ex. 5**

[http://www.cadmusgroup.com/wp-content/themes/cadmus/images/cadmus_logo_small.png]<http://www.cadmusgroup.com>

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<https://twitter.com/CadmusGroup> [LinkedIn] <http://www.linkedin.com/company/the-cadmus-group>

To: Yohannes, Lia[Yohannes.Lia@epa.gov]
Cc: Ridley, Caroline[Ridley.Caroline@epa.gov]
From: Frithsen, Jeff
Sent: Thur 2/26/2015 2:45:40 AM
Subject: HFDWA: Comments on Chapter 3
HFDWA - Chapter 3 - smaller jbf.docx

See Attached. Thanks Lia. This chapter is coming along very nicely.

Jeff

Jeffrey B. Frithsen, Ph.D.

National Center for Environmental Assessment

Office of Research and Development

U.S. Environmental Protection Agency

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Washington, DC 20460

703-347-8623 (office phone)

Physical Office Address/Overnight Deliveries

Two Potomac Yard (North Building), Room N-7741

2733 South Crystal Drive, Arlington, VA 22202

To: Ridley, Caroline[Ridley.Caroline@epa.gov]
From: Frithsen, Jeff
Sent: Thur 2/26/2015 2:44:24 AM
Subject: HFDWA: Comments on Chapters 1 and 2
HFDWA - Chapter 2 - smaller jbf.docx
HFDWA - Chapter 1 jbf.docx

See attached.

Jeffrey B. Frithsen, Ph.D.

National Center for Environmental Assessment

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Washington, DC 20460

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Physical Office Address/Overnight Deliveries

Two Potomac Yard (North Building), Room N-7741

2733 South Crystal Drive, Arlington, VA 22202

To: Frithsen, Jeff[Frithsen.Jeff@epa.gov]
Cc: Ridley, Caroline[Ridley.Caroline@epa.gov]
From: Shari Ring
Sent: Thur 2/26/2015 2:24:05 AM
Subject: RE: EPA Computer Hardware "Refresh"

I had to be first this time, as the afternoon was sucked up with meetings

I got 3 emails Jeff, which I'll save for the morning, and let you both know what we can do by COB tomorrow.

"Frithsen, Jeff" <Frithsen.Jeff@epa.gov> wrote:

Ex. 5

Ex. 5

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Shari Ring [Ex. 4]
Sent: Wednesday, February 25, 2015 9:09 PM
To: Frithsen, Jeff
Subject: Re: EPA Computer Hardware "Refresh"

Somebody should point out to them that "new computer" kills fewer electrons than "hardware refresh."
"Frithsen, Jeff" <Frithsen.Jeff@epa.gov> wrote:
I note that the hardware "refresh" (i.e., we get new computers) is occurring at the same time we are working hard to complete multiple HF Study products. I am ever hopeful that we all find this action refreshing and encounter few difficulties. That said, just a small reminder to back-up early, often, and perhaps in multiple places!

Schedule for Potomac Yards North is 3/23/15 to 4/27/15.

Schedule for RRB is 3/23/15 to 5/21/15.

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Noel, Glenda **On Behalf Of** Blancato, Jerry
Sent: Wednesday, February 25, 2015 8:44 PM
Subject: News from OSIM - Hardware Refresh and More

Non-Responsive

Non-Responsive

Jerry N. Blancato, PhD

Senior Information Officer

US EPA Office of Research and Development

and

Director

Office of Science and Information Management

US EPA Office of Research and Development

919-541-2854

Blancato.Jerry@epa.gov

To: Ridley, Caroline[Ridley.Caroline@epa.gov]
From: Knightes, Chris
Sent: Wed 2/25/2015 9:25:47 PM
Subject: thoughts on Chapters 1 and 2

Ex. 5

Chapter 1:

Ex. 5

Chapter 2:

Ex. 5

To: Ridley, Caroline[Ridley.Caroline@epa.gov]; Deniz (Inci)
Demirkanli Ex. 4
Shari.Ring Ex. 4
From: Kraemer, Stephen
Sent: Tue 2/24/2015 6:04:58 PM
Subject: FW: Interesting discussion in WRR regarding faults and HF fluid migration
Lefebvre_etal_2015_WRR_reply_G13.pdf
Flewelling_Sharma_2015_WRR_discussion_G13.pdf
Gassiat_etal_2014_WRR_HF_faulted_sedimentary_basins_contamination_shallow_aquifers_long_time.pdf

Ex. 5

Stephen R. Kraemer, Ph.D, Research Hydrologist
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Ecosystems Research Division

960 College Station Road

Athens, GA 30605-2700

voice (706) 355-8340

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kraemer.stephen@epa.gov

From: Kraemer, Stephen
Sent: Tuesday, February 24, 2015 10:08 AM
To: 'Jonny Rutqvist'; George Moridis; 'Matthew Reagan'
Subject: Interesting discussion in WRR regarding faults and HF fluid migration

FYI

Stephen R. Kraemer, Ph.D, Research Hydrologist
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WATER RESOURCES RESEARCH, VOL. 49, 8310–8327, doi:10.1002/2013WR014287, 2013

Hydraulic fracturing in faulted sedimentary basins: Numerical simulation of potential contamination of shallow aquifers over long time scales

Claire Gassiat,[1] Tom Gleeson,[1] René Lefebvre,[2] and Jeffrey McKenzie[3]

Received 17 June 2013; revised 9 October 2013; accepted 23 October 2013; published 12 December 2013.

[1] Hydraulic fracturing, used to economically produce natural gas from shale formations, has raised environmental concerns. The objective of this study is to assess one of the largely unexamined issues, which is the potential for slow contamination of shallow groundwater due to hydraulic fracturing at depth via fluid migration along conductive faults. We compiled publically available data of shale gas basins and hydraulic fracturing operations to develop a two-dimensional, single-phase, multispecies, density-dependent, finite-element numerical groundwater flow and mass transport model. The model simulates hydraulic fracturing in the vicinity of a permeable fault zone in a generic, low-recharge, regional sedimentary basin in which shallow, active groundwater flow occurs above nearly stagnant brine. A sensitivity analysis of contaminant migration along the fault considered basin, fault and hydraulic fracturing parameters. Results show that specific conditions are needed for the slow contamination of a shallow aquifer: a high permeability fault, high overpressure in the shale unit, and hydrofracturing in the upper portion of the shale near the fault. Under such conditions, contaminants from the shale unit reach the shallow aquifer in less than 1000 years following hydraulic fracturing, at concentrations of solutes up to 90% of their initial concentration in the shale, indicating that the impact on groundwater quality could be significant. Important implications of this result are that hydraulic fracturing should not be carried out near potentially conductive faults, and that impacts should be monitored for long timespans. Further work is needed to assess the impact of multiphase flow on contaminant transport along natural preferential pathways.

Citation: Gassiat, C., T. Gleeson, R. Lefebvre, and J. McKenzie (2013), Hydraulic fracturing in faulted sedimentary basins: Numerical simulation of potential contamination of shallow aquifers over long time scales, Water Resour. Res., 49, 8310–8327, doi:10.1002/2013WR014287.

1. Introduction

[2] Over the past 15 years, shale gas has emerged as a viable and important energy resource. In order to produce economically viable quantities of natural gas from unconventional reservoirs such as shale, the technique of hydraulic fracturing (hydrofracturing or ''fracking'') is generally used [BAPE, 2011; EPA, 2012]. Hydraulic fracturing consists of injecting high volumes of ''fracturing fluid'' at pressures greater than lithostatic, causing the formation to fracture and thereby increase its local permeability [EPA, 2012]. After hydraulic fracturing the pressure is relieved by the ''flowback,'' composed of fracture fluid and formation fluids, which returns to the surface [Gregory et al., 2001]. The fracking fluid is commonly composed of ffi99.5% water and proppants (generally sand), and ffi0.5% chemical additives including acids, solvents, and biocides [BAPE, 2011; Gregory et al., 2011]. Additionally, the flowback not only contains saline formation fluids and natural gas but also naturally occurring contaminants present in the host shale rocks such as radioactive compounds and heavy metals [Gregory et al., 2001; Groundwater Protection Council and All Consulting, 2009].

[3] Concerns about the potential environmental impact of hydraulic fracturing have increased, especially risks relating to drinking water resources [Kargbo et al., 2010; EPA, 2012]. Potential drinking water issues include: (1) water resource stress due to water withdrawal; (2) water pollution related to spills and leaks at above ground hydraulic fracturing operations; (3) unsuitable treatment of wastewater; (4) failures of wells in the shallow subsurface due to poor cementing or steel casing corrosion; and (5) geologic failures at depth as a result of the fracturing that could cause potential contamination of

This article was published with an incorrect title on 12 December 2013. This error was corrected on 18 December 2013.

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0043-1397/13/10.1002/2013WR014287

shallow groundwater aquifers via preferential pathways [EPA, 2012]. Some of these issues can be addressed by better design and the application of stringent regulations. However, the impact and potential of contamination of groundwater over long time scales aquifers related to the fracturing of the target shale unit is unclear. Although fluid migration rates are usually extremely slow in deep sedimentary systems, heterogeneities such as faults can provide preferential pathways [Garven, 1995; Person et al., 1996] through which fluids carrying contaminants may migrate more rapidly to reach shallow aquifers.

[4] The potential contamination of shallow aquifers from fluids originating from gas-bearing shales via preferential pathways such as faults has been acknowledged [BAPE, 2011; EPA, 2012], but is often considered negligible compared to other potential drinking water issues related to shale gas exploitation. This type of contamination has been considered as highly unlikely because (1) no fracking fluid has yet been found in drinking water wells [Osborn et al., 2011]; (2) the significant distance between the shale unit (at depths up to a few thousand meters) and the shallow aquifers (at less than a few hundred meters depth) would not lead to contaminant migration over short timescales [Alpha Environmental Consultants, 2009; Zoback et al., 2010; BAPE, 2011; Howarth et al., 2011]; (3) the formations above the shale unit often contain low-permeability lithologies that would decrease further the rate of transport [Arthur et al., 2008; BAPE, 2011]; (4) it is very unlikely that hydraulic fractures would propagate over such long distances to directly connect the gas shale and shallow aquifers [Zoback et al., 2010]; (5) fault reactivation due to hydraulic fracturing would likely occur on small distances of a few meters [EPA, 2012]; and (6) during gas production, downwards and horizontal flow to the horizontal shale gas well would be promoted, decreasing the risk of upwards migration [Howarth et al., 2011].

[5] Conceptually, although fluid migration rates are usually extremely slow in deep sedimentary basins, migration of contaminants from the gas shale driven by an overpressured shale gas formation to a shallow aquifer may be possible if hydraulic fracturing induces communication with other fluid conductive paths, such as faults or production wells. If conductive paths are present from the gas-bearing shale to shallower depths, the long distances and low-permeability units may not act as sufficient barriers for fluid flow to shallow aquifers. Furthermore, although fluid flow toward horizontal shale gas wells would be enhanced during gas production, it may not be the case once production has stopped as overpressure may still remain in the gas shale. Finally, the lack of observed contamination of drinking water wells, after less than 30 years of shale gas hydraulic fracturing, does not preclude future groundwater contamination.

[6] We discern three scenarios in which a hydraulically conductive fault zone could represent a potential pathway for contamination from a hydraulic fracture zone: (1) hydraulic fracturing reactivates a nearby fault zone due to the stress regime in the formation causing additional deformation and offset; (2) hydraulic fractures may develop from the production well to the fault zone, potentially increasing the size or permeability of the damage zone associated with the fault; and (3) the fault zone may act as a hydraulic conduit, even without interaction with hydraulic fractures. Fault zone reactivation and the loss of hydraulic fracturing fluids into fault zones suggest these scenarios are plausible. Fault slippage and reactivation [Sibson, 1990; Zoback, 2007] is caused by liquid or gas injection [Streit and Hillis, 2004; Soltanzadeh and Hawkes, 2009; Konstantinovskaya et al., 2012], or by the depletion of fluid pressures during production [Streit and Hillis, 2004]. Additionally faults are controlled by shear and normal stress components on the fault plane [Nacht et al., 2012], fault orientation [Rudnicki, 2002; Soltanzadeh and Hawkes, 2009], and the reservoir geometry and dip angle [Soltanzadeh and Hawkes, 2008]. Fault zone reactivation due to hydraulic fracturing has been reported by several microseismic studies and is one of the most common anomalies identified using microseismic measurements [Cipolla et al., 2011]. During hydraulic fracturing operations, faults are generally avoided when drilling as they give rise to a number of problems. The negative impact of fracturing in the vicinity of a fault zone are a decreased hydraulic fracturing of the target formation, a potential increase in flowback water, and a significant cost to the operator in terms of time and materials [Wessels et al., 2011]. Several reports underline the issues related to fault zone reactivation in hydraulic fracturing operations [Soltanzadeh and Hawkes, 2008; Maxwell et al., 2009; Soltanzadeh and Hawkes, 2009; Cipolla et al., 2011; Wessels et al., 2011], suggesting that fracturing in the proximity of permeable fault zones at depth is not an uncommon occurrence.

[7] Although fault zones can clearly be permeable hydraulic features at the typical depth range of prospective shale gas formations (0.5–4.5 km [EIA, 2011b]), an important question is whether fault zones could be continuous permeable features from the depth of shale gas formations to near the surface. Fault zones have a complex hydraulic structure that can be barriers, conduits, or conduit-barriers [Caine et al., 1996; Aydin, 2000; Rawling et al., 2001; Bense and Person, 2006; Bense et al., 2013]. Techniques for predicting low permeability fault zones in sedimentary basins, called ''fault seals'' have been described in the petroleum literature. For example, the shale gouge ratio [Yielding et al., 1997] uses the estimated clay-content of faults to determine the sealing capacity of the fault. However, multiple lines of evidence suggests faults in sedimentary basins can also be conduits of gas, petroleum, and mineral deposits [Moretti, 1998; Pinti and Marty, 2000; Boles et al., 2004; Muchez et al., 2005; Person et al., 2008; Pfaff et al., 2010]. Mineral deposits, such as Carlin and Mississippi Valley type, located along faults indicate that extensional fault zones have transient permeability fields that are conductive from kilometers depth to shallow depths at least episodically over geologic time [Muchez et al., 2005; Person et al., 2008; Pfaff et al., 2010]. Correlations between noble gas concentrations and geological features suggest the upwards migration of gas and deep fluids through fractures and faults [Lombardi and Pinti, 1992]. Hydrocarbon modeling and observation suggests even very narrow, transient, and moderately permeable faults can focus the migration of hydrocarbons [Moretti, 1998; Pinti and Marty, 2000; Boles et al., 2004]. Fault zones in siliciclastic sedimentary basins are often sand-

shale gouges acting as complex conduit-barrier systems with transient fault permeability structures likely evolve on short to geological timescales [Faulkner et al., 2010]. The gas, mineral, and petroleum observations, as well as the evidence of fault zone reactivation and the loss of hydrofracturing fluids into fault zones at depth, suggest that some fault zones could be hydraulically conductive from the shale gas formation to shallow depths. For any given basin, actual sedimentary, stress, structural, and hydraulic conditions will have to be assessed to identify the potential presence of hydraulically conductive faults. Previously, a simple groundwater flow and transport model simulated the migration of contaminants from a shale formation to shallow depths through a fault zone [Myers, 2012]. However, the conclusions drawn from this model have been questioned because of the simplifications and assumptions of this model including unrealistic boundary conditions and using a constant density, finite-difference, single-phase simulator [Saiers and Barth, 2012; Cohen et al., 2013]. Thus, there is a need for more realistic modeling of these fault processes for a better understanding of the risks associated with contamination of shallow aquifers due to hydraulic fracturing.

[8] The objective of this study is to assess whether hydraulic fracturing could lead to contamination of shallow aquifers via preferential fluid migration along faults, and what factors control the potential for significant contaminant transport into shallow aquifers. To achieve these objectives we: (1) compiled publically available data on shale gas formations, fault parameters, and hydraulic fracturing operations; (2) used a numerical model to simulate the effect of shale gas fracturing in a generic faulted sedimentary basin that is representative of the data from multiple basins; and (3) conducted a sensitivity analysis with the model to examine the sensitivity of contaminant transport to basin, fault, and hydraulic fracturing parameters that covers the range of parameters found in literature. The numerical model is a two-dimensional, single-phase, multispecies, density-dependent, finite-element numerical groundwater model, and is used to assess the solute transport potential along a fault zone, from a shale formation to a shallow aquifer, following hydraulic fracturing.

2. Generic Model

[9] We systematically reviewed publically available data to develop a generic model representative of shale gas basins (Table 1). Sedimentary basins are layered hydrogeologic systems that are often deformed by multiple crosscutting fault zones. Prospective shale gas formations are generally at depths of 1–4 km [EIA, 2011a] and occur in regions of low to moderate topography. The distance between major regional faults in rift or foreland basins is a few kilometers, such as in the St. Lawrence lowlands where the Utica shale is found [Séjourné et al., 2013]. The permeability of shale gas formations is extremely low and these formations are often overpressured, partially due to the low permeability combined with the internal gas generation [Soltanzadeh and Hawkes, 2009]. The permeability of the sedimentary rocks overlying the shale gas formations can be low to moderate ($10^{2\,20}$ to $10^{2\,13}$ m^2) [Gleeson et al., 2011; Séjourné et al., 2013]. In this section, we discuss the basin, fault, and hydraulic fracturing parameters used to develop a generic model.

[10] Although more complex and heterogeneous permeability patterns are common in many sedimentary basins, we simulate a simplified system in order to isolate the mechanisms of transport of contaminants present in fluid migrating along a fault due to hydraulic fracturing. We develop a model of a generic, regional sedimentary basin based on hydrological and geological properties of multiple basins with shale gas formations. Primarily, we gathered information on the Utica shale gas development in the St. Lawrence lowlands, QC, Canada, located between the Yamaska fault and the Logan's Line [Lavoie et al., 2008; BAPE, 2011; Rivard et al., 2012; Séjourné et al., 2013] because this was the most readily available to the authors. In addition, wherever possible, we gathered data on other active shale gas formations, primarily the Barnett shale in Texas and Marcellus shale in New York and Pennsylvania [Montgomery et al., 2005; Arthur et al., 2008; Lavoie et al., 2008; Sumi, 2008; EIA, 2011b; Davies et al., 2012]. In general, the data from the St. Lawrence lowlands (such as the depth to shale) is consistent with other areas of shale gas development (Table 1). However, there are differences in the St. Lawrence lowlands compared to other gas shales, such as the low permeability unit overlying the shale gas formation. We examine the sensitivity to basin model parameters within the range indicated in Table 2.

[11] Shale gas formations can be underpressured, at hydrostatic pressure, or overpressured. The Utica shale in the St. Lawrence lowlands, the Barnett shale, and the northern part of the Marcellus formation are overpressured [Montgomery et al., 2005; Lavoie et al., 2008; Sumi, 2008; Rivard et al., 2012]. Moreover, ffi40% of the prospective areas for shale gas extraction globally are overpressured [EIA, 2011a]. Therefore, we simulate a scenario of an overpressured shale formation, under a pressure gradient of 13 kPa/m. If the pressure gradient is lower (either in a less overpressured or underpressured formation), the potential for contaminant migration would decrease. The impact of the pressure gradient in the shale is examined with the sensitivity analysis.

[12] High salinities are common in sedimentary basins and most sedimentary basins are saturated with brine. The transition from shallow fresh groundwater to saline fluids is commonly at a few hundred meters depth [Globensky, 1972; Connolly et al., 1990; Kharaka and Thordsen, 1992; Björlykke and Gran, 1994; Hanor and McIntosh, 2007]. In North America, salinities up to 500 g/L have been reported at depths less than 4 km [Kharaka and Thordsen, 1992]. In the St. Lawrence lowlands, salinities of 175 g/L have been reported in the Trenton group, below the Utica shale, which occurs at depths of 800–2000 m [Ngoc et al., 2011]. Higher salinities, due to their effect on water density, reduce the potential for vertical groundwater flow from the shale gas formation to the shallow aquifer.

[13] As discussed above, fault zones can be hydraulic barriers, conduits, or conduit-barriers [Caine et al., 1996; Aydin, 2000; Rawling et al., 2001; Bense and Person, 2006]. We simulate a relatively simple scenario of a single fault zone that is a continuous, high permeability conduit from the shale gas formation to the shallow aquifer, as a potential worst-case scenario. If the fault zone is

Table 1. Compilation of Parameter Values Reported in the Literature From Quebec (QC), New York (NY), Texas (TX), Pennsylvania (PA), and Other Regions

Parameter	Range of Values	References
Basin Parameters		
Permeability above shale	Fine-grained sediments: $10^{2\,17}$ m^2	Gleeson et al. [2011]
	Coarse-grained sediments: $10^{2\,13}$ m^2	
Permeability of shale	$10^{2\,23}$ to $10^{2\,17}$ m^2	Neuzil [1994]
	$10^{2\,20}$ to $10^{2\,16}$ m^2	Freeze and Cherry [1979]
	$10^{2\,23}$ to $10^{2\,20}$ m^2	Flewelling and Sharma [2013]
	Utica (QC): 9 3 $10^{2\,23}$ to 8 3 $10^{2\,17}$ m^2	Séjourné et al. [2013]
	Marcellus (NY, PA): 2 3 $10^{2\,16}$ m^2	Soeder [1988]
	Barnett (TX): < $10^{2\,17}$ m^2	Montgomery et al. [2005]
Porosity above shale	Sandstone: 5–30%	Freeze and Cherry [1979]
	Shale: < 10%	
	Utica (QC): 1.2–3.2%	Rivard et al. [2012]
Porosity of shale	5–60% at 0.3–10 km depth	Neuzil [1994]
	< 10%	Freeze and Cherry [1979]
	US: 1–12%, median: 7%	EIA [2011b]
	Utica (QC): 0.7–6.6%	Lavoie et al. [2008], BAPE [2011], Rivard et al. [2012], and Séjourné e t a.l [2013]
	Marcellus (NY, PA): 8%	EIA [2011b]
	Barnett (TX): 5%	EIA [2011b]
Topographic gradient	St. Lawrence lowlands (Utica): 2.3 6 2.7%	
	Appalachian basin (Marcellus): 2.5 6 2.9%	
	Fort Worth basin (Barnett): 1.0 6 0.7%	
Matrix compressibility	Jointed rock: $10^{2\,10}$ to $10^{2\,8}$ $Pa^{2\,1}$	Freeze and Cherry [1979]
	Sound rock: $10^{2\,11}$ to $10^{2\,9}$ $Pa^{2\,1}$	
Pressure gradient in shale	Utica (QC): 10–17 kPa/m	Lavoie et al. [2008], BAPE [2011], Rivard et al. [2012], and Séjourné e t a.l [2013]
	Marcellus (NY, PA): northern basin overpressured	Sumi [2008]
	Barnett (TX): 10.4–11.8 kPa/m	Montgomery et al. [2005] and Lavoie et al. [2008]
	World[a]: 40% overpressured	EIA [2011a]
Depth to saline formations	North America: 0–2 km	Kharaka and Thordsen. [1992]
	Utica (QC)[b]: 86–1554 m	Séjourné et al. [2013]
	Utica (QC): 150–740 m	Globensky [1972]
Salinity	North America: 0–500 g/L	Kharaka and Thordsen. [1992]
	Utica (QC), shallow depths: 5–225 g/L	Globensky [1972]
	Utica (QC), high depths[c]: 100–240 g/L	Ngoc et al. [2011]
Depth to shale gas formation	World: 1–4.5 km, average: 2.9 km	EIA [2011a]
	US: 0.5–4.5 km, average: 2.3 km	EIA [2011b]
	Utica (QC)[d]: 1.2–2.5 km	BAPE [2011]
	Marcellus (NY, PA)[e]: 1.2–2.6 km	Arthur et al. [2008]
	Barnett (TX): 1.9–2.6 km, average: 2.3 km	Arthur et al. [2008] and EIA [2011b]
Thickness of shale gas formation	World: 20–300 m, average: 77 m	EIA [2011a]
	US: 7–940 m, average: 190 m	EIA [2011b]
	Utica (QC): 220 m on average	BAPE [2011]
	Marcellus (NY, PA): 15 to 60 m	Arthur et al. [2008]
	Barnett (TX): 30–280 m, average: 91 m	Arthur et al. [2008] and EIA [2011b]
Fault Parameters		
Distance between faults	Utica (QC): 0.6–27.7 km, average: 6.6 km	Séjourné et al. [2013]
Hydraulic Fracturing (HF) Parameters		
Length of hydrofracturing zone	1–3 km	Rivard et al. [2012]
	1.2 km	Zoback et al. [2010]
Vertical extent of hydraulic fractures	100–300 m	Rivard et al. [2012]
	Barnett (TX): 46 m above and 61 m below the wellbore	Zoback et al. [2010]
	Barnett (TX): < 588 m	Davies et al. [2012]
	Marcellus (NY, PA): < 536 m	
	Most <90 m	King [2012]
Permeability of hydrofracturing zone	100–1000 times the permeability of the formation	King [2012]

[a]Potential shale gas development in 48 countries.
[b]Saline water index. The interval between the fresh water and saline water index is often of a few hundred meters, which does not allow to accurately locate the transition between fresh water and brine.
[c]Formations below the Utica shale (Postdam and Beekmantown groups).
[d]Only the area of interest for shale gas development, between the Yamaska fault and the Logan Line, has been considered.
[e]Marcellus shale targeted for exploitation.

Table 2. Parameter Values Used in the Base Case Model and Range of Variation for Sensitivity Analysis

Parameter	Base Case Value	Range of Variation for Sensitivity Analysis
Basin Parameters		
Permeability above shale (m^2)	$10^{2\ 15}$	$10^{2\ 18}$ to $10^{2\ 13}$
Porosity above shale	0.03	0.01–0.1
Topographic gradient	0.002	0.0004–0.01
Matrix compressibility ($Pa^{2\ 1}$)	$10^{2\ 8}$	$10^{2\ 9}$ to $10^{2\ 7}$
Overpressure in shale (kPa/m)	13	9–25
Fault Parameters		
Permeability of fault above shale (m^2)	$10^{2\ 13}$	$10^{2\ 15}$ to $10^{2\ 11}$
Permeability of fault in shale (m^2)	$10^{2\ 18}$	$10^{2\ 20}$ to $10^{2\ 16}$
Fault anisotropy above shale	1	1–1000
Fault anisotropy in shale	1	1–1000
Fault orientation relative to horizontal a (ff)	135	30–150
Hydraulic Fracturing (HF) Parameters		
Permeability of HF zone (m^2)	$10^{2\ 17}$	$10^{2\ 19}$ to $10^{2\ 15}$
Distance from HF zone to fault zone (m)	0	0–1000
Thickness of shale above HF zone (m)	25	0–50
Length of HF zone (km)	2	1–3
Thickness of HF zone (m)	150	60–200

more of a barrier (either continuously or at specific depths), the potential for transport through the fault would be reduced or potentially negligible. We simulate the effect of reducing fault permeability as well as the case of conduit-barrier by changing the anisotropy (the ratio of permeability along fault to permeability perpendicular to fault) instead of simulating a discrete low permeability fault core flanked by a high permeability damage zone [Caine et al., 1996].

[14] In hydrofracturing operations, a horizontal well is drilled within the shale formations for a length of a few kilometers and hydraulic fracturing is performed in stages at intervals of tens of meters [Zoback et al., 2010]. Hydraulic fractures can extend up to a few hundred meters above and below the horizontal wellbore [Zoback et al., 2010; Davies et al., 2012; King, 2012] and can increase the permeability of the formation up to three orders of magnitude [King, 2012]. The shale gas formations are generally thin (less than 100 m in most major U.S. shale gas development) [EIA, 2011b], especially in comparison to the thickness that is typically affected by hydraulic fracturing. The goal of hydraulic fracturing is to develop the maximum contact with the producing formation, while minimizing fracturing of formations above or below which can lead to additional costs in terms of fracking fluid, pressure loss, and time [King, 2012]. Therefore, we assume that hydrofractured zones can extend to the top of the shale gas formation. We do not simulate the actual geomechanical deformation of hydraulic fracturing but rather the impact of increased permeability due to hydraulic fracturing. We focus on the period after hydraulic fracturing because the pressure pulse of hydraulic fracturing would rapidly decay and would not have a significant impact on the migration of contaminants over long time scales, which is the focus of the present study. For ductilely deformed shale formations, permeability from hydrofracturing may be temporally reduced on decadal timescales, which would reduce contamination potential.

3. Numerical Methods and Parameter Values

[15] Simulations were conducted with SUTRA-MS, a US Geological Survey numerical variable-density simulator of groundwater flow as well as the transport of multiple-solutes [Voss and Provost, 2002; Hughes and Sanford, 2005]. The base case value of each parameter of interest and its range of variation in the sensitivity analysis are presented in Table 2 and other properties used for all simulations are presented in Table 3. The model domain consists of a vertical cross-section of a 50 km long, 2 km deep portion of a sedimentary basin (Figure 1) with a linear topographic gradient. To simulate the type of nested, active groundwater flow that occurs in undulating topography [Tóth, 1963], we imposed five recharge areas at the upper boundary, alternating with six specified pressure boundaries (P 5 0) which represent discharge areas such as surface water bodies. The lateral sides and base of the model domain are no-flow boundaries. Permeability and thickness of the shallow aquifer were assigned based on field data from the St. Lawrence lowlands and the recharge rate was adjusted in order to result in a realistic depth of the active flow zone (Table 2). A 3.5 mm/year value of recharge was chosen so that the active flow zone is limited to approximately the first 200 m below the surface for the permeability and geometry of the 100 m thick shallow aquifer. Although this is a lower recharge rate than expected in the St. Lawrence lowlands, this study focuses on deep groundwater flow from the shale unit to shallow aquifers, and a modification of the recharge rate would not impact the results in terms of solute mass fluxes reaching the freshwater aquifer, although the concentrations of these solutes

Table 3. Parameters Used in All Simulations

Parameter	Value
Liquid Water	
Fluid compressibility ($(m\,s^2)/kg$)	$4.47\ 3\ 10^{2\ 10}$
Fluid viscosity ($kg/(m\,s)$)	$1.0\ 3\ 10^{2\ 3}$
Initial salt concentration below 200 m (kg/m^3)	100
Solid Matrix	
Solid matrix compressibility ($(kg/(m\,s^2))^{2\ 1}$)	$1.0\ 3\ 10^{2\ 8}$
Density of solid grains (kg/m^3)	2650
Porosity in the upper layer	0.3
Porosity in the middle and shale layers	0.03
Permeability in the upper layer (m^2)	$1\ 3\ 10^{2\ 13}$
Permeability in the middle layer (m^2)	$1\ 3\ 10^{2\ 15}$
Permeability in the shale layer	$1\ 3\ 10^{2\ 20}$
Basin anisotropy k_x/k_z	100
Other	
Gravity (m/s^2)	2 9.81
Longitudinal dispersivity (m)	10
Transverse dispersivity (m)	1
Transport	
Molecular diffusivity of solutes in pure fluid (m^2/s)	$1.0\ 3\ 10^{2\ 9}$
Fluid base density (kg/m^3)	1000
Coefficient of fluid density change with concentration of salt ($kg^2/(m^3\,kg)$)	700
Coefficient of fluid density change with concentration of tracers ($kg^2/(m^3\,kg)$)	0
Upper Boundary	
Fluid source rate at recharge nodes (mm/yr)	3.5

in the aquifer would be lower if more important recharge and groundwater flow occurred in the freshwater aquifer.

[16] The basin contains three layers (Figure 1): (1) a 200 m thick, low permeability unit at the base of the model domain representing the shale gas unit; (2) a relatively permeable bedrock layer overlying the shale; and (3) a highly permeable, 100 m thick layer at the top of the basin representing a shallow unconsolidated aquifer. Depths and thicknesses of the different units were derived based on the St. Lawrence lowlands (structural corridor C of Séjourné et al. [2013]) and are representative of typical basins with shale gas extraction. Each unit is assumed to be homogeneous and anisotropic (k_x/k_z 5 100). Permeabilities and porosities of the three units were derived from data and literature values of the St. Lawrence lowlands. We assigned the permeability of the shale unit at $10^{2\,20}$ m^2 by considering (1) the usual range of shale permeability (Table 1); (2) the relationship of permeability with depth usually observed [Ingebritsen et al., 2006]; and (3) the capacity to maintain overpressure over geological time scales.

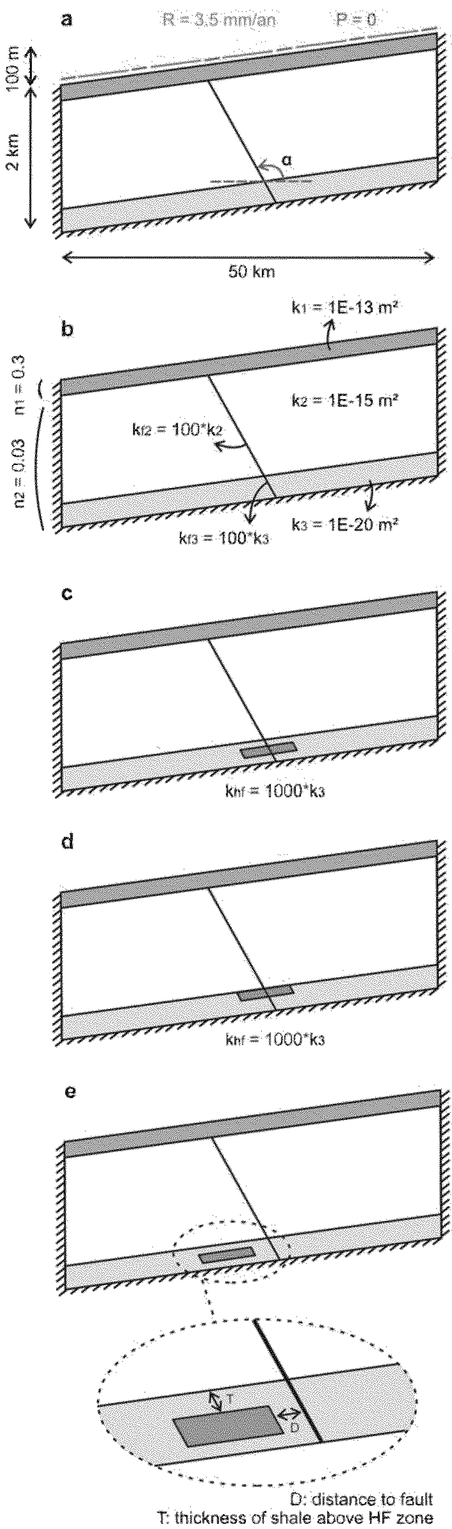

Figure 1.

[17] A 10 m wide, continuous normal fault zone is located in the middle of the model domain, and crosscuts the entire thickness of the bedrock but not the shallow, unconsolidated aquifer (Figure 1). This fault thickness is consistent with a regional fault with hundreds of meters of displacement [Childs et al., 2009]. An isotropic permeability of two orders of magnitude higher than the permeability of the surrounding material is assigned to the fault zone. Fault anisotropy, defined as the ratio of permeability along fault to permeability perpendicular to fault, is studied in the sensitivity analysis. In the sensitivity analysis of the anisotropy ratio, permeability along fault is left unchanged while permeability perpendicular to fault is reduced.

[18] Considering a single fault zone is consistent with the fault density in the St. Lawrence lowlands and the purpose of the study. The spatial density of major faults in the St. Lawrence lowlands (Table 1) suggests that a single horizontal well would not likely cross more than one fault zone [Séjourné et al., 2013]. The purpose of the simulations is a process-based understanding of contaminant transport potential, and not on the estimation of the total cumulative fluxes of contaminants that could migrate along faults due to regional-scale hydraulic fracturing of a gas shale unit.

[19] The shale is considered overpressured, with a pressure gradient of 13 kPa/m [Lavoie et al., 2008; Rivard et al., 2012; Séjourné et al., 2013], which corresponds to an overpressure of 6 MPa at 1.9 km depth (Figure 2). Brine has been observed at a few meters to a few hundred meters depth in the St. Lawrence lowlands [Séjourné et al., 2013],

Figure 1. General setup of the numerical model (not to scale): (a) model domain and boundary conditions. R stands for recharge and P is pressure relative to atmospheric conditions. The angle a measures the fault orientation relative to horizontal; (b) permeability and porosity of the different units; (c) base case scenario with hydraulic fracturing in the middle of the shale; and (d) base case scenario with hydraulic fracturing at the top of the shale. Hydraulic fracturing is modeled by an increase of permeability in the hydraulic fracturing zone (in blue). In the base case, the hydraulic fracturing zone crosses the fault zone; (e) scenario where the hydraulic fracturing zone does not cross the fault zone. T is the thickness of shale above HF zone and D is the distance of hydraulic fracturing (HF) zone to fault zone.

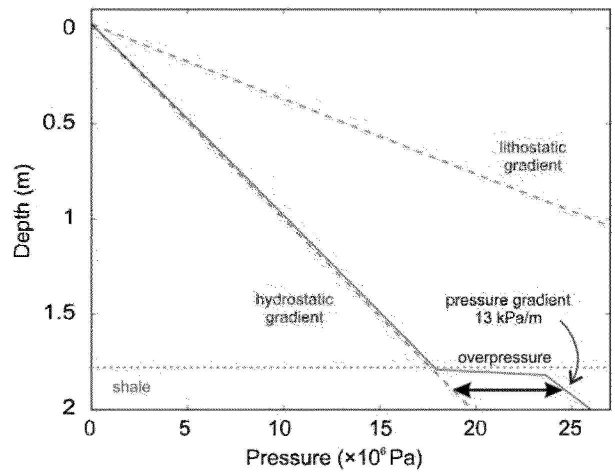

Figure 2. Initial pressure variation with depth at x 5 10 km. A pressure gradient in the shale of 13 kPa/m corresponds to an overpressure of 6 MPa in the middle of the shale at 1900 m depth.

and high salinities of 175 g/L have been reported in the Trenton group, below the Utica shale [Ngoc et al., 2011]. Therefore, the concentration of brine was assigned as 100 g/L below 200 m depth. As a comparison, water is often considered as nonsaline when the concentration of salt is below 4 g/L [BAPE, 2011]. Hydraulic fracturing was simulated by increasing the permeability of a 2 km long, 150 m thick zone in the vicinity of the fault. Two base case scenarios were simulated, with the hydraulic fracturing zone located either in the middle of the shale unit (Figure 1c) or at the top of the shale unit (Figure 1d) since the width of the hydrofracturing zone relative to the thickness of shale gas formations suggests this is likely common. In both scenarios, the hydrofractured zone crosses the fault. In the sensitivity analysis, we laterally moved the hydraulically fractured zone away from the fault.

[20] The 46,060 element numerical mesh is shown in Figure 3. Grid spacing telescopes from 1 m 3 10 m finite elements (vertical 3 horizontal extent) in the fault zone to 200 m 3 30 m elements in regions most distal from the fault. Horizontal discretization is 1 m for elements in the

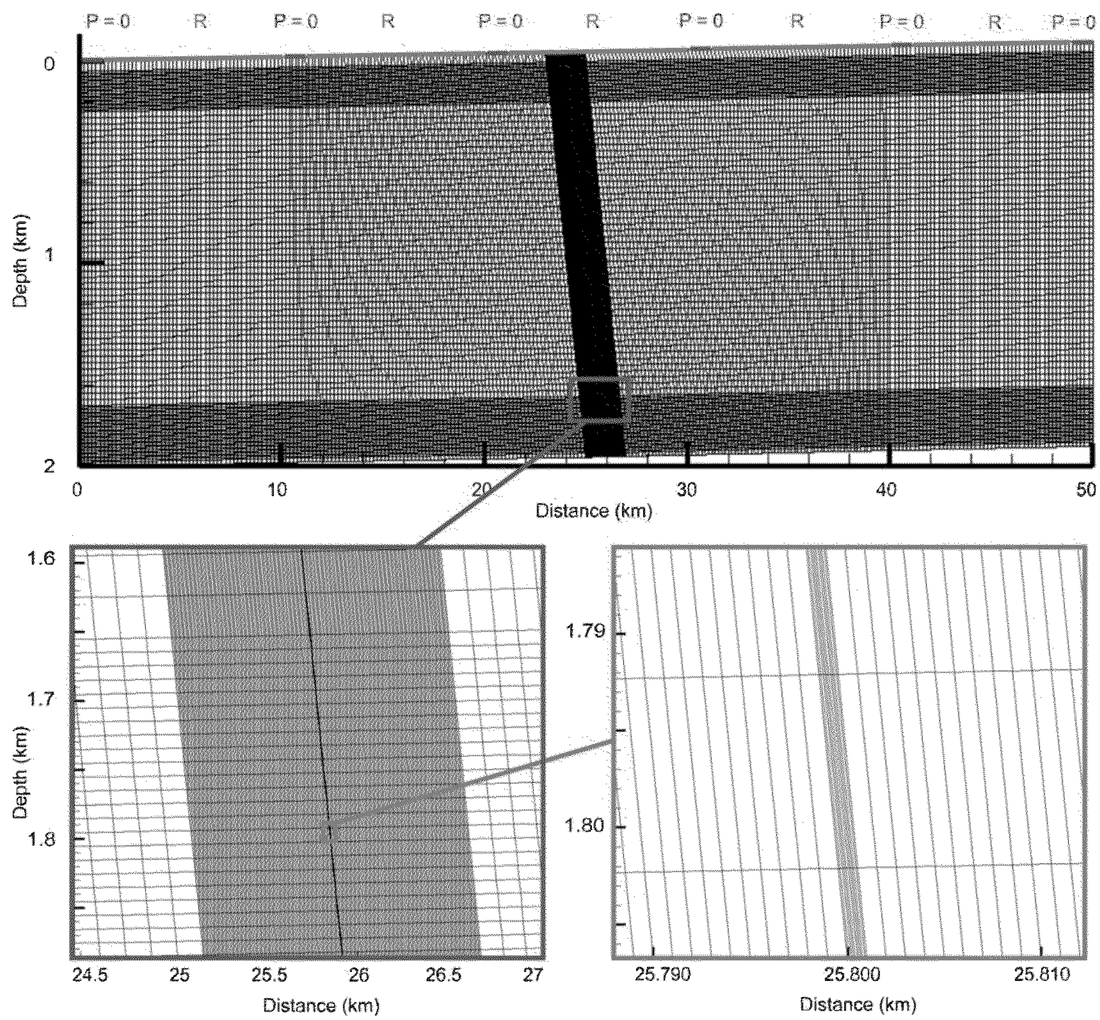

Figure 3. Finite-elements mesh used for the numerical simulation. (top) Five recharge areas (R, in blue) were imposed at the upper boundary, alternating with six specified pressure boundaries (P 5 0, in red) which represent discharge areas. The lateral sides and base of the model domain are no-flow boundaries.

fault zone, 10 m for elements within 1 km of the fault zone, and 200 m for elements at greater distances. Vertical discretization is 10 m in the upper (20–200 m depth) and lower (1700–2000 m depth) parts of the model domain and 30 m in between. Doubling the grid refinement showed that results were not sensitive to grid resolution. At each time step, the flow and transport equations were solved using Gaussian elimination [Voss and Provost, 2002].

[21] Simulations were conducted in two consecutive runs. An initial 300,000 year run was used to reach steady-state pressure and solute conditions. In this initial run, the pressure gradient in the shale is specified and the brine concentration below 200 m depth is also specified. The output from this run was used as initial conditions for a second run, in which pressure and concentration are not specified [Saiers and Barth, 2012; Cohen et al., 2013]. This second simulation was run over 100,000 years to assess whether the pressure field and the concentration field were stable. The dissipation of the pressure gradient within the shale was negligible over 100,000 years when the permeability in the shale unit was $10^{2\,20}$ m^2. A 5000 year period in the middle of the second simulation was thus selected as the time examined (t 5 0 2 5000 years) to assess potential contamination for hydrofracturing scenarios (by modifying permeability of the hydrofractured zone at t 5 0 years) or without hydrofracturing. The initial hydraulic head distribution and concentration field at t 5 0 years are presented in Figures 4a and 4b. For each simulation, initial time-step size was set at 1 year. Time-step size was incremented by a factor of 1.5 every 10 time steps until the maximum time step size of 10 years is reached. Reducing the time step showed that results were not sensitive to the time steps used.

[22] Three passive tracers were simulated in order to study the movement in regional groundwater flow due to hydraulic fracturing (Figure 4). At t 5 0, the first tracer, herein called the ''shale tracer'' is located in the shale layer (2 2000 < z < 2 1800); the second tracer, herein called the ''lower basin tracer,'' is located in the lower part of the overlying unit (2 1800 < z < 2 1000); and the third tracer, herein call the ''upper basin tracer,'' is located in the upper part of the overlying unit (2 1000 < z < 2 200) up to the fresh water aquifer. We define the depth of potential contamination as the shallowest depth relative to the land surface where the concentration of the shale tracer is above 1% of its initial concentration in shale. The shale tracer represents any potential contaminant originating from the shale unit: chemicals in fracking fluid initially after fracturing, or naturally occurring contaminants in the shale such as radioactive materials or heavy metals for the entire duration of simulations. The value of 1% of initial concentration is arbitrary; other cut offs such as 10% of initial concentration were also examined, and show a similar behavior in sensitivity analysis as discussed below. We compiled the mass fluxes of the three tracers at the top of the fault (i.e., at the base of the shallow freshwater aquifer). We assumed that the initial concentration of TDS in the shale and lower basin was 100 kg/m^3 and calculated the sum of fluxes from the shale and the lower basin in order to estimate the total mass flux of potential contaminants in the shallow aquifer. The upper basin tracer was not considered as there is no clear influence of hydraulic fracturing on its migration.

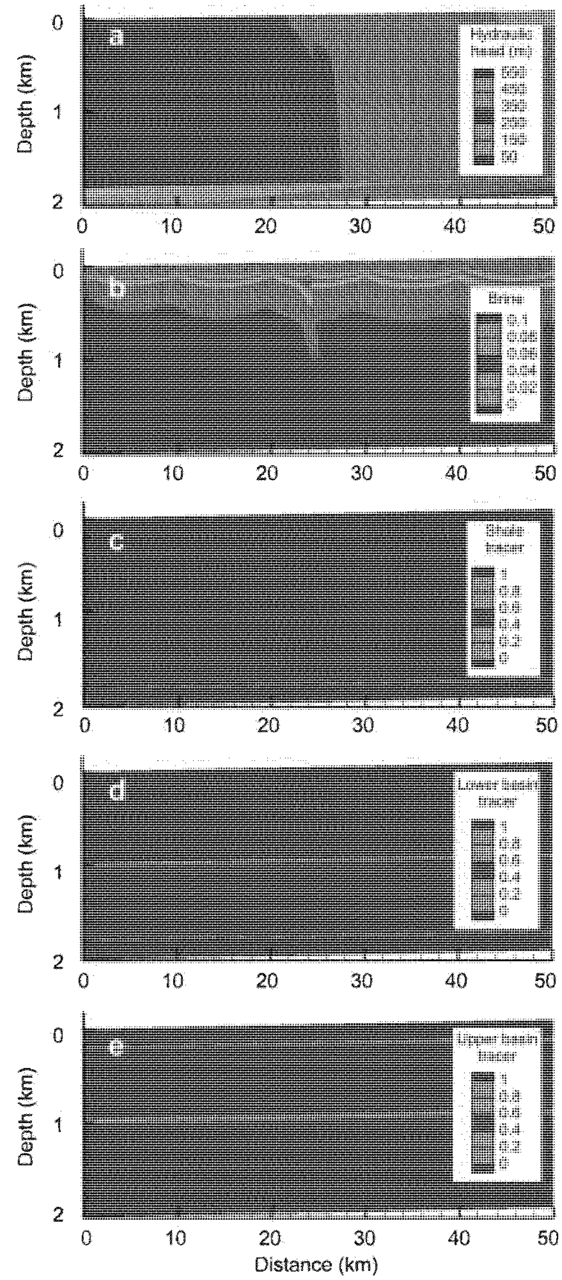

Figure 4. Initial conditions of the base case scenario: (a) initial hydraulic head distribution. In the base case scenario, the shale is overpressured; (b) initial concentration of brine; (c) initial concentration of the shale tracer; (d) initial concentration of the lower basin tracer; and (e) initial concentration of the upper basin tracer.

4. Results

[23] Figure 5 compares the simulated spatial distribution of the shale tracer for the case without hydraulic fracturing (Figure 5a), for the base case scenario with hydraulic fracturing in the middle of the gas shale (Figure 5b), and for the base case scenario with hydraulic fracturing at the top of the gas shale (Figure 5c). No shale tracer migration occurs along the fault without hydraulic fracturing (Figure 5a). For the base case scenarios, shale tracers move up the fault after hydraulic fracturing (Figures 5b and 5c). The

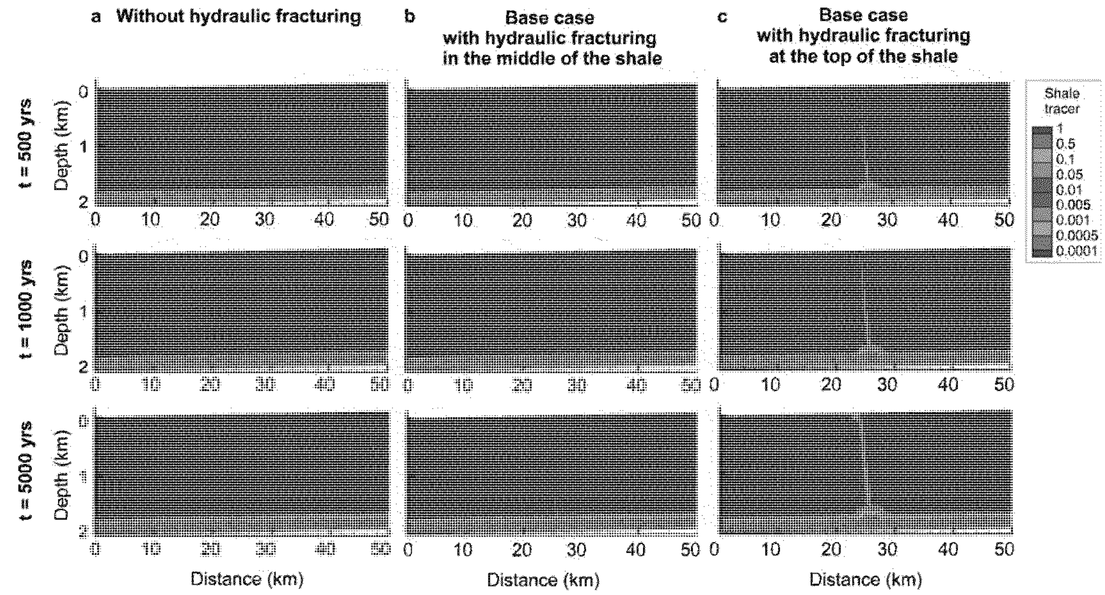

Figure 5. Migration of shale tracer through time: (a) without hydraulic fracturing; (b) with hydraulic fracturing in the middle of the gas shale (first base case scenario); and (c) with hydraulic fracturing at the top of the gas shale (second base case scenario).

base case with hydraulic fracturing in the middle of the shale formation leads to slow migration, which is indicated by the 1% concentration threshold reaching only 1500 m depth at simulation time of 5000 years (apparent on the lower graph of Figure 5b). With hydraulic fracturing at the top of the shale gas formation (Figure 5c), the 1% concentration threshold reaches 500 m depth after about 500 years and the upper part of the fault after about 1000 years. After 5000 years, a plume of shale tracer reaches the shallow aquifer with concentrations up to 5% of the initial tracer concentration in shale. Therefore, in this scenario, the shallow aquifer is significantly contaminated by the tracer from the shale formation. Figure 6 shows the extent and relative concentration of the shale tracer (Figure 6a) and the lower basin tracer (Figure 6b) in the active freshwater flow zone at t 5 5000 years in the base case scenario with hydraulic fracturing at the top of the shale (lower graph of Figure 5c). The lateral plume of concentrations of shale tracer higher than 0.01 (1%) in the active zone is 500 m, and the extent of concentrations higher than 0.001 (0.1%) is 1.2 km (Figure 6a). The plume with concentrations of shale tracer higher than 0.01 (1%) in the active zone is 300 m, and the extent of concentrations higher than 0.001 (0.1%) is 1 km (Figure 6b). Maximum concentrations of the shale tracer and lower basin tracer in the shallow aquifer are ffi5%.

[24] For the base case simulations, Figure 7 shows the migration through time of the three tracers (Figure 4), without hydraulic fracturing or with hydraulic fracturing either in the middle of the shale (Figures 7a and 7c) or at the top of the shale (Figures 7b and 7d). Figure 7 compares tracer migration through time with or without hydraulic fracturing (Figures 7a and 7b), and for thresholds of 1% and 10% of initial concentration (Figures 7c and 7d). The shale tracer, which is initially in the shale, migrates higher upwards when there is hydraulic fracturing in the middle of the shale than without, 300 m compared to 100 m over 5000 years (Figure 7a). The lower basin tracer also moves up the fault, which is consistent with flow in the overlying unit being more significant than in the shale. However, the importance of this migration is quite similar with or without hydraulic fracturing; about 400 m upwards (Figure 7a). The difference in migration of the shale tracer between the case with hydraulic fracturing than without is a lot more apparent when the hydraulic fracturing occurs at the top of the fault, 1700 m compared to 50 m over 1500 years (Figure 7b). In this case, migration of the lower basin tracer is also more important with hydraulic fracturing than without, 900 m compared to 200 m over 1500 years. There is no clear influence of hydraulic fracturing on the migration of the upper basin tracer, which mimics the spatial distribution of solutes in the upper part of the overlying aquifer unit due to active fresh groundwater flow (Figures 7a and 7b). The depths of 1% and 10% concentration thresholds through time have the same pattern (Figures 7c and 7d), so we use a concentration of 1% as the cutoff for the remainder of the analysis. The lower elevation of the 10% concentration, compared to the 1% concentration, is indicative of dispersive effect on the transport of the tracer, either within the fault or due to the exchange of fluid with units adjacent to the fault. The following sections focus on the migration of the shale tracer, from the shale unit, as the potential impact of hydraulic fracturing on groundwater quality in the shallow aquifer is expected to be more related to fluids originating from the shale horizon.

[25] Sensitivity analysis of a variety of basin, fault, and hydraulic fracturing parameters shows that only a few parameters control contaminant migration potential from the gas shale to the shallow aquifer following hydraulic fracturing in the middle of the shale (Figure 8). First, the impact of the following basin parameters were analyzed (Figures 8a, 8d, 8g, 8j, and 8m): pressure gradient in shale, permeability of the unit overlying the shale, topographic

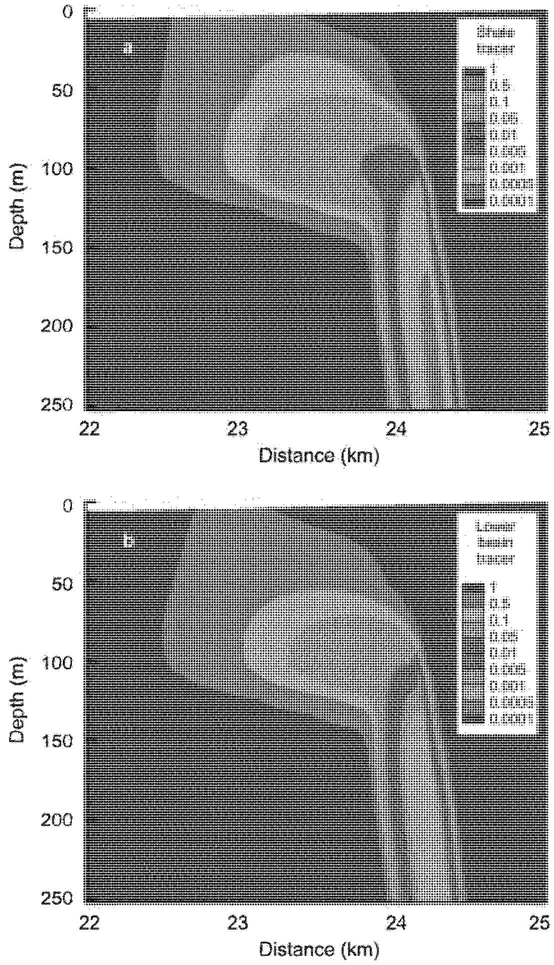

Figure 6. Extent of contamination in the shallow aquifer. Concentration of (a) shale tracer and (b) lower basin tracer in the shallow aquifer at t 5 5000 years for the base case scenario with hydraulic fracturing at the top of the fault.

gradient, matrix compressibility, and porosity of the unit overlying the shale. The simulation results indicate that the only sensitive basin parameter is the pressure gradient in the shale. Depth of potential contamination decreases systematically with an increase of the pressure gradient in the shale (Figure 8a) as upward flow is driven by the overpressure in the shale. Pressure gradients above 13 kPa/m (overpressure in the middle of the shale above 6 MPa) lead to contamination above 1500 m depth within 5000 years. The other basin parameters have a limited impact on potential contamination indicated by a shale tracer relative concentration of 1% for the model conditions of the base case.

[26] Second, various fault parameters were examined (Figures 8b, 8e, 8h, 8k, and 8n): fault permeability in the unit overlying the shale, fault permeability in shale, fault dip, fault anisotropy in the unit overlying the shale, and fault anisotropy in shale. The simulations show that fault permeability in the shale is the most important parameter, with a higher permeability in the fault resulting in faster migration (Figure 8e). Fault permeability above $10^{2\,17}$ m^2 leads to contamination above 1000 m depth within 5000 years. All other fault parameters studied have a limited impact on potential contamination for the base case model conditions.

[27] Third, the effect of hydraulic fracturing parameters was studied (Figures 8c, 8f, 8i, 8l, and 8o): hydrofracturing (HF) zone permeability, distance of the hydrofracturing zone to fault, thickness of shale above the hydrofracturing zone, length of hydrofracturing zone, and thickness of hydrofracturing zone. The depth of potential contamination varies greatly depending on the thickness of shale above the hydrofracturing zone (Figure 8i). Migration of solutes is very slow if the thickness of shale above the hydrofracturing zone is more than 20 m, whereas it is fast when the thickness of shale above the fractured zone is less than 20 m because fluids from the shale travel to the fault through the overlying formation as well as through the hydrofractured zone of the shale formation. In our simulations, the thickness of shale above the hydrofracturing zone appears as the most important parameter controlling the migration along the fault. The other hydraulic fracturing parameters have a limited impact on potential contamination. In summary, when hydraulic fracturing occurs in the middle of the shale, the most important parameters controlling contaminant transport potential are parameters that control migration to the fault in the overlying unit: pressure gradient in shale, fault permeability in shale, and thickness of shale above hydrofracturing zone.

[28] Another set of sensitivity analysis with the same basin, fault, and hydraulic fracturing parameters was conducted with the hydraulic fracturing zone at the top of the shale unit (Figure 9). Overall, the contamination migration is faster and reaches shallower depths at greater concentrations, in part due to rapid transport through the overlying formation. The most sensitive basin parameters (Figures 9a, 9d, 9g, 9j, and 9m) are the pressure gradient in the shale and the permeability of the overlying unit. The speed of migration along the fault increases with the overpressure in shale, and contamination of shallow aquifers is likely to occur as a result of overpressured shales only (pressure gradient in shale > 10 kPa/m) (Figure 9a). A decrease in permeability of the overlying unit leads to slower migration along the fault (Figure 9d). Conversely, potential contamination is largely insensitive to the topographic gradient. The most crucial fault parameter (Figures 9b, 9e, 9h, 9k, and 9n) is fault permeability in the overlying unit (Figure 9b). The change in depth of contamination through time is negligible over the studied variations of fault permeability in shale, fault dip, fault anisotropy in the overlying unit, and in shale (Figures 9e, 9h, 9k, and 9n). Finally, some hydraulic fracturing parameters have an impact on potential contamination (Figures 9c, 9f, 9i, 9l, and 9o). Speed of migration along the fault increases with increasing values of the hydraulic fracturing zone permeability (Figure 9c). Potential contamination occurs at shallower depth when the hydraulic fracturing zone is close to the fault zone (Figure 9f). Length and thickness of the hydraulic fracturing zone have a limited impact on potential contamination (Figures 9l and 9o). In this case, the thickness of shale above the hydraulic fracturing zone appears as the most important parameter controlling the migration along the fault (Figure 9i).

[29] Figure 10 shows the concentration of shale tracer and lower basin tracer at the top of the fault and base of the shallow aquifer following hydraulic fracturing at the top of the fault for several values of pressure gradient in the shale, porosity above shale, fault permeability above shale, fault

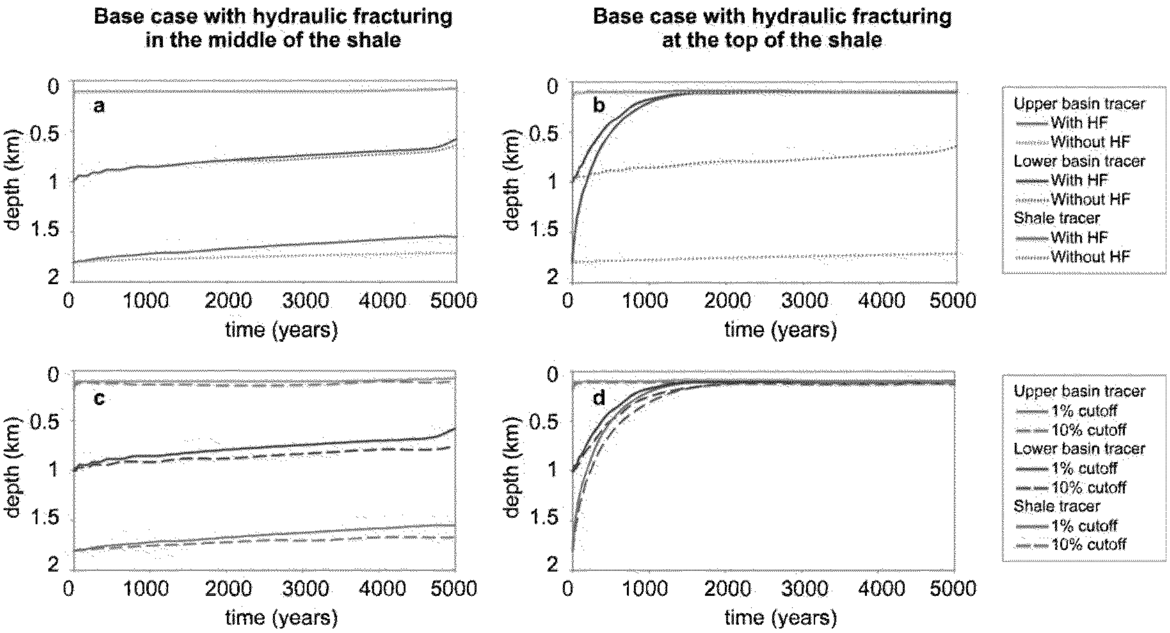

Figure 7. Depth from the land surface of potential contamination from the three tracers through time for the base case with hydraulic fracturing (HF) in (a and c) the middle or (b and d) at the top of the shale gas formations. With and without hydraulic fracturing, with a 1% concentration threshold: (a) with hydraulic fracturing in the middle of the shale and (b) with hydraulic fracturing at the top of the shale. With hydraulic fracturing with a 1% and 10% thresholds: (c) with hydraulic fracturing in the middle of the shale and (d) with hydraulic fracturing at the top of the shale.

orientation, and hydrofractured zone permeability. Concentration of the shale tracer at the top of the fault is 0.01 at 5000 years under a shale pressure gradient of 13 kPa/m (overpressure of 6 MPa in the middle of the shale), and greatly increases under pressure gradients above 15 kPa/m (overpressure of 10 MPa in the middle of the shale) with concentrations up to 0.9 at 5000 years (Figure 10a). Concentrations of the lower basin tracer are slightly lower (Figure 10c), with a maximum concentration of 0.1 at the top of the fault at 5000 years under a pressure gradient in the shale of 16 kPa/m (overpressure of 12 MPa in the middle of the shale). Concentrations of lower basin tracer decrease under pressure gradients above 16 kPa/m. This could be due to the fact that more fluid migrates along the fault as the pressure gradient in shale increases, which includes fluids from the shale and the lower basin up to a pressure gradient of 16 kPa/m. Above that value, the migration of fluids from the shale unit is so dominant that fluids from the overlying unit enter the fault to a lesser degree. Other parameters such as the fault permeability in the overlying unit and the fault orientation also have an impact on the concentrations of tracers at the base of the shallow aquifer following hydraulic fracturing at the top of the shale. If the fault zone has a very high permeability (ffi$10^{2\ 11}$ m^2) concentrations of both the shale tracer and the lower basin tracer reach 0.3 at 5000 years (Figures 10e and 10f). A vertical fault zone leads to a concentration of shale tracer of 0.2 and a concentration of lower basin tracer of almost 0.1 at 5000 years (Figures 10g and 10h). Variations of other variables do not lead to high concentrations being transported (Figure 10).

[30] We also compute mass fluxes at the top of the fault (i.e., at the base of the shallow aquifer) by assuming that the initial concentration of TDS in the shale and lower basin was 100 kg/m^3. Figure 11a shows the potential sum of fluxes from the shale and the lower basin through time for the scenarios without hydraulic fracturing and for the base cases with hydraulic fracturing in the middle of the shale or at the top of the shale. Fluxes reach 180 g/yr/m following hydraulic fracturing at the top of the shale. Figure 11b shows the potential sum of fluxes from the shale and the lower basin under several pressure gradients in the shale following hydraulic fracturing at the top of the shale. Fluxes reach 3 3 10^4 g/yr/m under high pressure gradients.

5. Discussion

[31] While it is often considered that fluid migration via natural preferential pathways carrying contamination from a gas shale unit to a shallow aquifer due to hydraulic fracturing is very unlikely [Arthur et al., 2008; Zoback et al., 2010; BAPE, 2011; Howarth et al., 2011; Osborn et al., 2011; EPA, 2012], the simulation results presented in this paper show that the migration of fluids and contaminants over long time scales along a fault zone to shallow aquifers can occur under certain conditions. This study considers the scenario of contamination of shallow aquifers due to migration of contaminants from the shale formation along a fault zone. This scenario is one of many that may lead to groundwater contamination due to shale gas development. Other scenarios, such as groundwater pollution due to spills and leaks at above ground hydraulic fracturing operations, or failures of wells at shallow depth due to poor cementing or steel casing corrosion, could cause contamination of groundwater resources on shorter timescales.

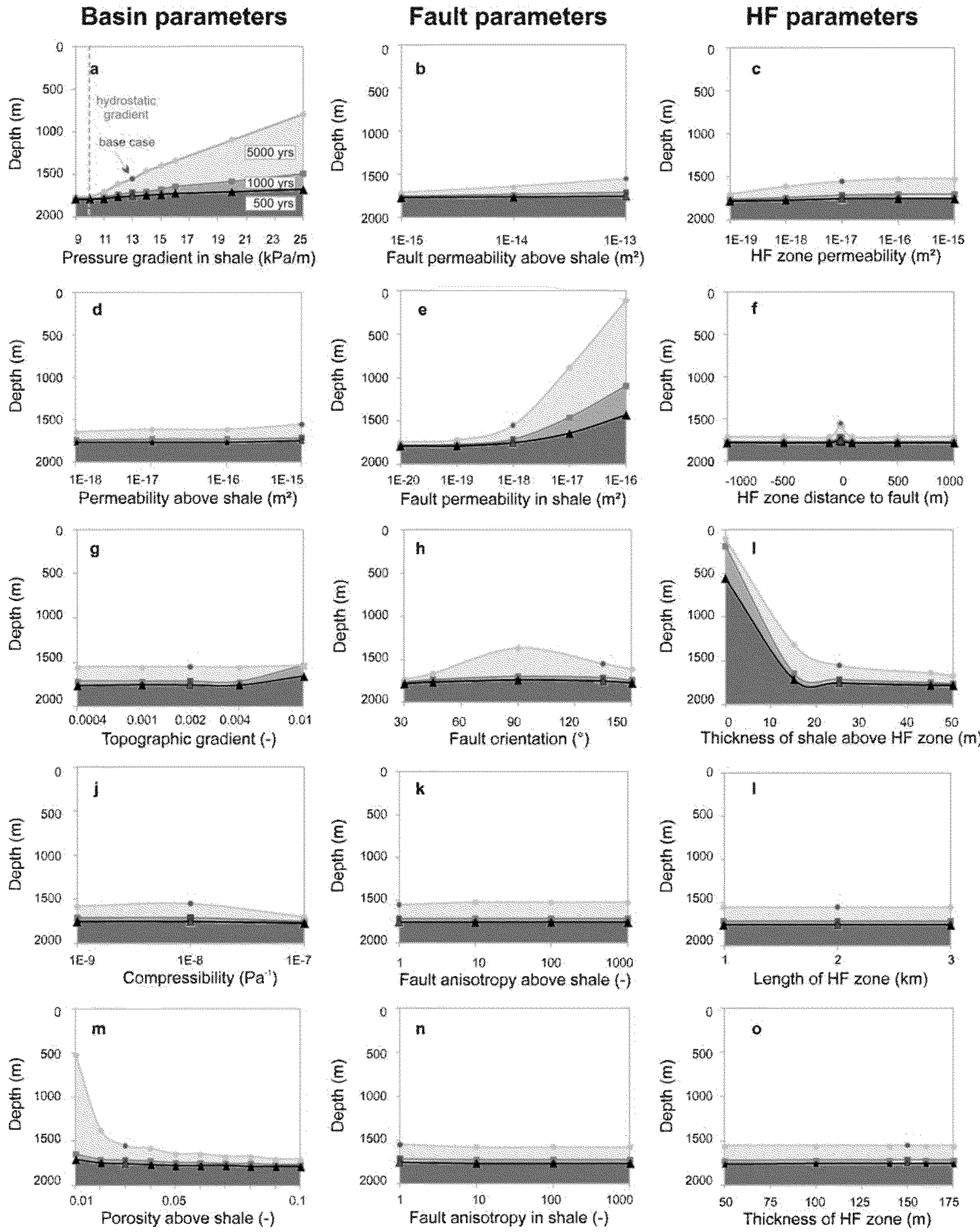

Figure 8. Sensitivity analysis with hydraulic fracturing (HF) in the middle of the shale. Depth relative to the land surface of potential contamination from the shale tracer depending on: (a) pressure gradient in shale; (b) fault permeability above shale; (c) HF zone permeability; (d) permeability above shale; (e) fault permeability in shale; (f) hydraulic fracturing (HF) zone distance to fault; (g) topographic gradient; (h) fault orientation; (i) thickness of shale above HF zone; (j) matrix compressibility; and (k) fault anisotropy above shale. Fault anisotropy is defined as the ratio of permeability along fault to permeability perpendicular to fault; (l) length of HF zone; (m) porosity above shale; (n) fault anisotropy in shale; and (o) thickness of HF zone. The lines and shading show the depth of potential contamination of a shale tracer relative concentration of 1% at t 5 500 years (black), t 5 1000 years (dark gray), and t 5 5000 years (light gray). The base case scenario with hydraulic fracturing in the middle of the shale is shown in red circles.

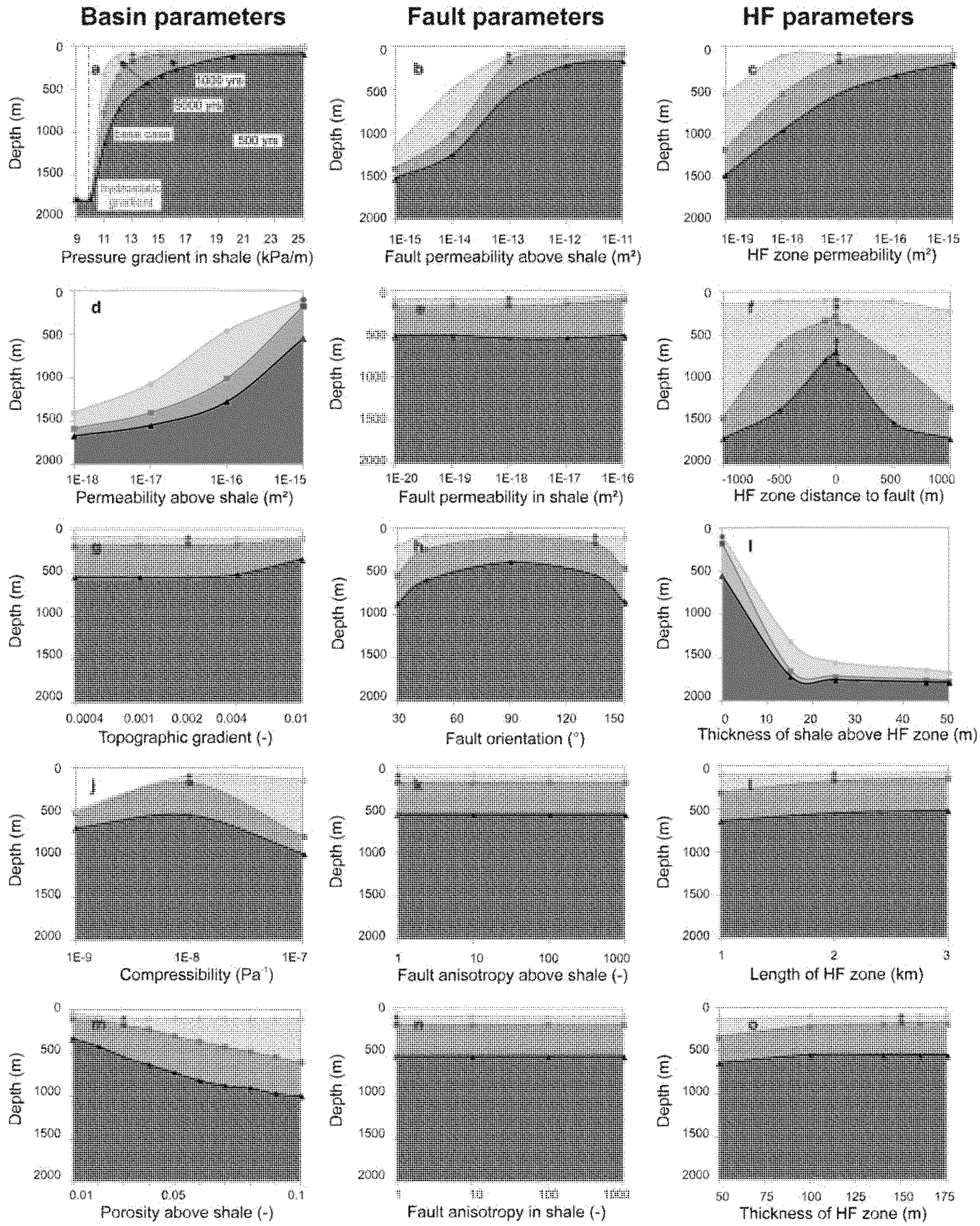

Figure 9. Sensitivity analysis with hydraulic fracturing (HF) at the top of the shale. Depth relative to the land surface of potential contamination from the shale tracer depending on: (a) pressure gradient in shale; (b) fault permeability above shale; (c) hydraulic fracturing (HF) zone permeability; (d) permeability above shale; (e) fault permeability in shale; (f) HF zone distance to fault; (g) topographic gradient; (h) fault orientation; (i) thickness of shale above HF zone; (j) matrix compressibility; and (k) fault anisotropy above shale. Fault anisotropy is defined as the ratio of permeability along fault to permeability perpendicular to fault; (l) length of HF zone; (m) porosity above shale; (n) fault anisotropy in shale; and (o) thickness of HF zone. The lines and shading show the depth of potential contamination of a shale tracer relative concentration of 1% at t 5 500 years (black), t 5 1000 years (dark gray), and t 5 5000 years (light gray). The base case scenario with hydraulic fracturing at the top of the shale is shown in red circles.

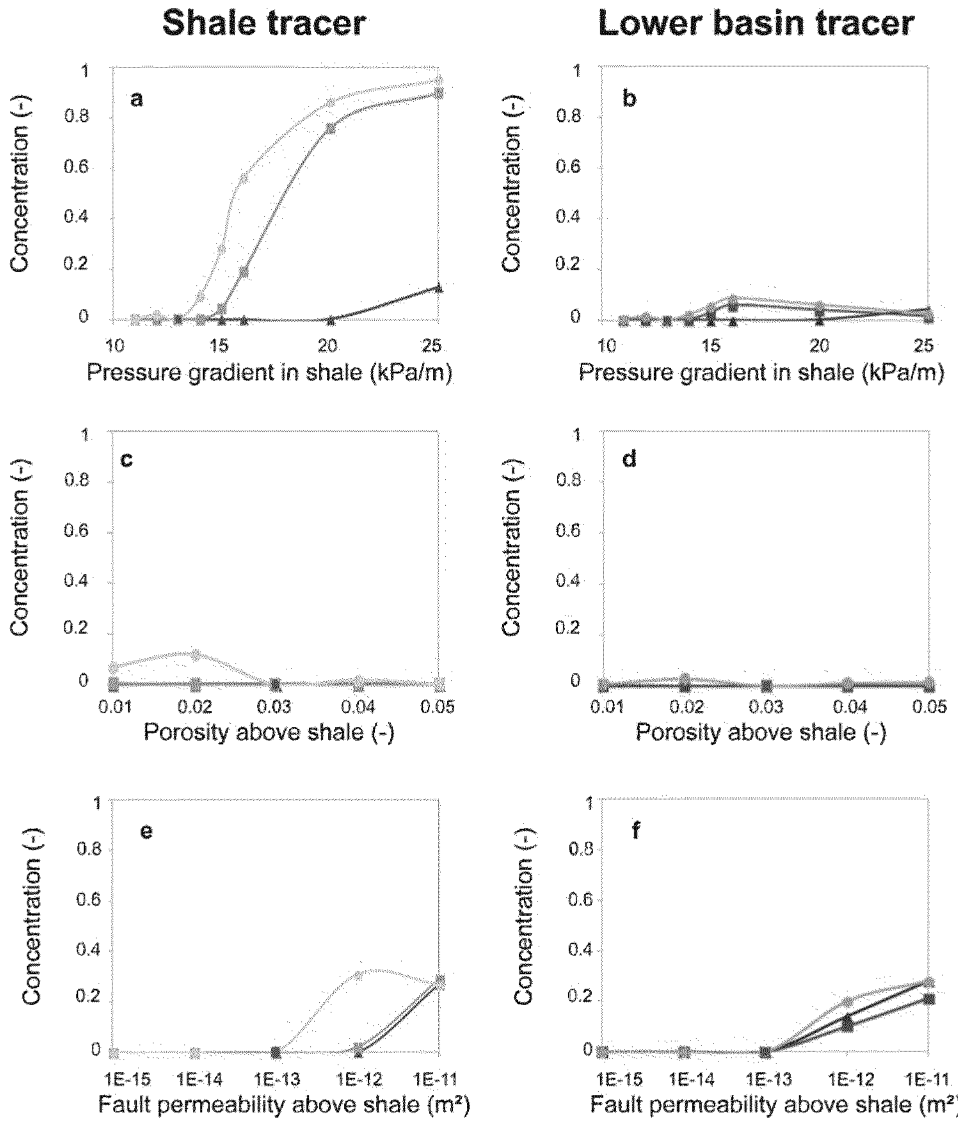

Figure 10. Concentrations at the base of the shallow aquifer. Concentration of (a, c, e, g, i) shale tracer and (b, d, f, h, j) lower basin tracer at the top of the fault following hydraulic fracturing at the top of the shale for several values of (a and b) pressure gradient in shale; (c and d) porosity above shale; (e and f) fault permeability above shale; (g and h) fault orientation; and (i and j) hydrofractured zone permeability. The lines show the depth of concentration of the shale (blue) or lower basin (green) tracer at the top of the fault at t 5 500 years (dark blue, dark green), t 5 1000 years (blue, green), and t 5 5000 years (light blue, light green). The base case scenario with hydraulic fracturing at the top of the shale is shown in red circles.

[32] Numerical simulations show that fluid flow and contaminant transport potential is significantly enhanced when the hydrofractured zone is near the top of the shale unit (Figure 8i). Most shale formations are very thin; almost 30% of shale gas formations in the US are less than 50 m thick, and more than 60% of shale gas formations in the US are less than 100 m thick [EIA, 2011b]. It is thus technically and economically difficult to preserve intact shale over tens of meters above the hydraulically fractured zone. Hydraulic fracturing near the top of a gas shale unit is thus a realistic scenario. Similarly, fracturing of the overlying formations is generally avoided but has been reported [Arkadakskiy and Rostron, 2013]. Operators use microseismic monitoring to verify that hydraulic fracturing is restricted the shale gas unit. However, seismic monitoring was conducted in only about 3% of the hydraulic fracturing stages performed in the United States in 2009 [Zoback et al., 2010]. It is thus difficult to evaluate how often the hydrofractured zone extends above the target formation. Although we did not simulate fracturing of the overlying formation, it is likely that this would highly increase the migration potential of contaminants along a fault according to the simulation results reported in this paper.

[33] In the case of hydraulic fracturing at the top of the shale, another crucial parameter controlling contaminant transport potential is the distance of the hydrofractured zone relative to the fault. Results show that with hydraulic fracturing at the top of the shale, migration rates greatly decrease for hydrofractured zones located from 500 to 1000 m away from the fault zone (Figure 9f). The average

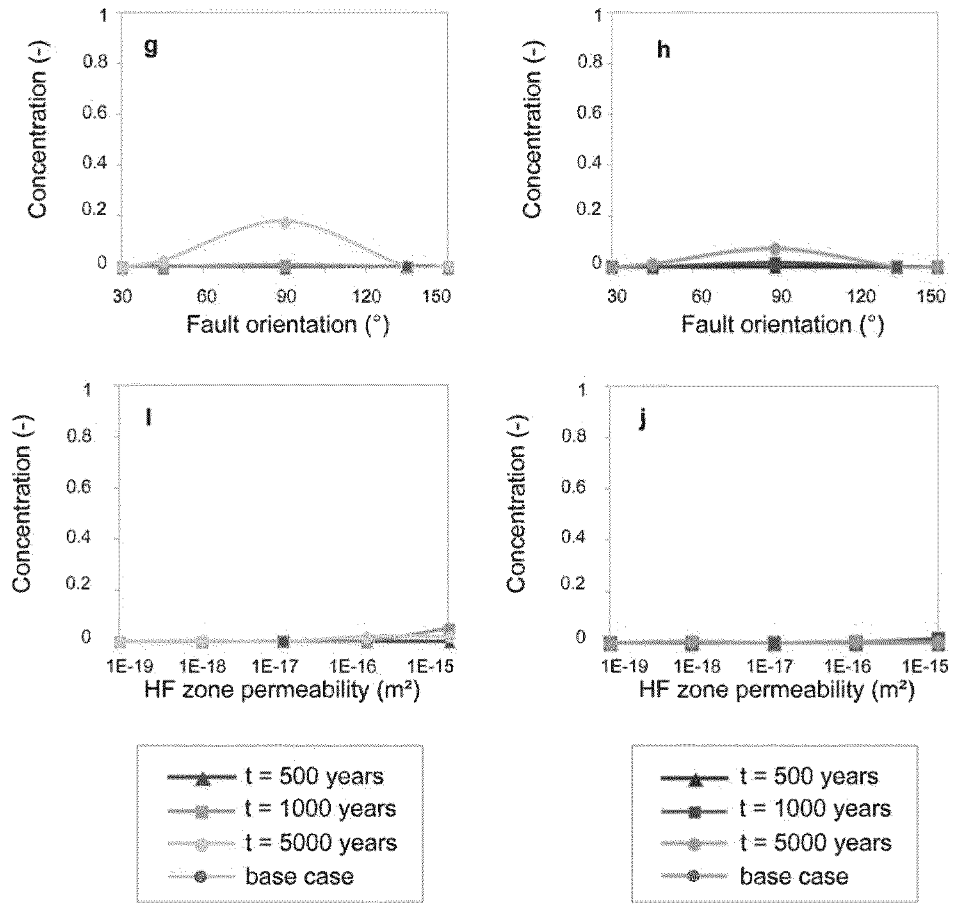

Figure 10. (continued)

distance between major faults is ffi6.6 km in the St. Lawrence lowlands [Séjourné et al., 2013] and horizontal wells are usually 1–3 km long [Rivard et al., 2012]. Regulations on well density and length as well as designing hydraulic fracturing zones a safe distance away from potentially conductive faults could greatly reduce the risk of groundwater contamination over long time scales due to migration via faults, although this assumes the three-dimensional distribution of faults zones is well defined and that the hydraulic properties of the fault zones is robustly characterized, with data publicly available for regulators and others to evaluate.

[34] Finally, basin and fault properties impact the migration potential. Numerical simulations show that matrix permeability and fault permeability in the overlying sediments highly affect the risk of contamination at shallow depths (Figures 9b and 9d). Additionally, pressure gradients within the shale are critical, as overpressured shales cause the upwards migration of contaminants, whereas migration rates are greatly reduced in hydrostatic and underpressured shales (Figure 9a). These basin and fault properties greatly vary between shale gas formations, and even potentially between faults within a basin, so knowledge of regional geologic, structural, and hydraulic properties would allow an initial assessment of contamination potential for a specific shale gas development. Depth to shale formation is also variable (500 m to 4.5 km in the United States) [EIA, 2011b]. Although we conducted simulations for a single value of depth to shale formation only (1.8 km), aquifer contamination should be more likely and rapid for shale formations at shallower depths.

[35] Simulation results show that for the base case scenario with hydraulic fracturing at the top of the shale, the extent of concentrations of shale tracer or lower basin tracer higher than 0.01 (1%) in the active zone is a few hundred meters, the extent of concentrations higher than 0.001 (0.1%) is ffi1 km, and maximum concentrations of the shale tracer and lower basin tracer in the shallow aquifer are 5% (Figure 6). However, values of relative concentrations and extent of plume in the shallow aquifer should be used with caution, as they depend on the density of contaminants and the lateral groundwater velocities in the active zone, which are not the focus of this study. Values of concentration at the base of the shallow aquifer (at the top of the fault) are more reliable. Simulations show that almost full concentration of the shale tracer and mass fluxes up to 10 kg/yr/m of TDS could reach the shallow aquifer under high pressure gradients in the shale, indicating that the impact on groundwater quality could be quite important (Figures 10a and 11).

[36] The results from this study are, in part, limited by some aspects of the numerical model used in this study:

[37] 1. We simulate single-phase flow, whereas shale formations contain gas, water, and sometimes oil. To better describe the migration of the gas phase, one should consider gas carried in solution by oil, gas carried in solution by water, and gas movement as a separate phase. In multiphase flow, buoyancy and capillary forces would impact

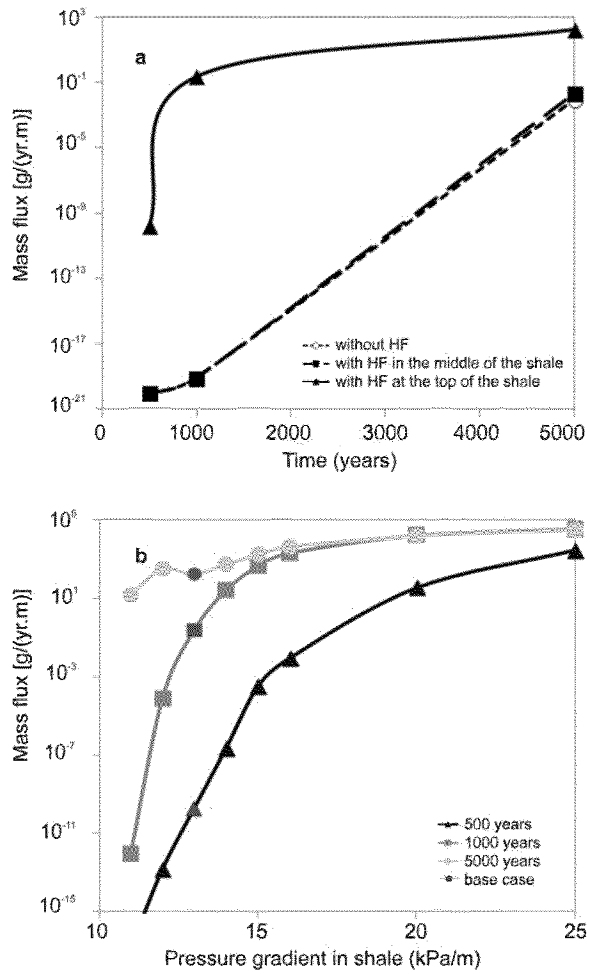

Figure 11. Comparison of the mass flux at the top of the fault against time and the pressure gradient in the shale. The fluxes were calculated by assuming the tracer in the shale and lower basin (at the top of the fault) had an initial concentration of TDS of 100 kg/m^3. (a) Mass flux through time for the three simulations shown in Figure 5 without hydraulic fracturing, with hydraulic fracturing in the middle of the shale and at the top of the shale and (b) mass flux with hydraulic fracturing under several pressure gradients in shale.

fluid flow by their opposite, competing effects [Ingebritsen et al., 2006]. The buoyancy force would increase the potential for contaminant migration, whereas capillary forces would decrease it. Furthermore, single-phase models do not describe the dynamic relationships between storage, permeability, and water content of the shale and overlying units that contain gas and are thus only partially saturated with water. Further work is needed to assess the impact of multiphase flow on this migration pattern.

[38] 2. We use a 2D cross-sectional model which implies the conditions of an infinitely extended fault and hydrofractured zone in the third dimension.

[39] 3. We simulate the impact of hydraulic fracturing by a change in permeability, without considering the pressure regime in the well during and after hydraulic fracturing operations. This is justified by the long-term simulation over several thousand years, long after gas well closure. However, we acknowledge that it could impact migration of contaminants in the first years to decades of shale gas extraction.

[40] 4. Initial pressure propagation associated with hydraulic fracturing was neglected as recent work suggests that the pressure perturbation is likely to be restricted to the vicinity of the hydraulic fractures [Flewelling and Sharma, 2013]. If pressure disturbances due to hydraulic fracturing persist for several years and affect an important volume of the formation, the upward transport of fluid could be accelerated.

[41] 5. We consider a stable sedimentary basin with generally low thermal gradient and simulate isothermal conditions. High thermal gradients would reduce the water density, which would enhance upward flow assuming permeability was large enough for buoyancy driven flow [Ingebritsen et al., 2006].

[42] 6. We consider regional faults, which may or may not be precisely located in 3D at the depth of shale gas formations.

[43] 7. In some simulations, we assume that the hydrofractured zone extends to the top of the shale over its entire length. However, in multistage fracturing, the first stages allow for adjusting the additional fracturing. A first stage of fracturing showing fluid losses due to connectivity with the zone above the shale unit would likely be corrected during the additional stages of hydraulic fracturing operations.

[44] 8. We assume that the hydrofractured zone and the fault zone have persistent high permeabilities. We acknowledge that fractures may close over the modeled time period, which would lead to a decrease in permeability and reduce the upwards migration of contaminants.

[45] 9. We do not account for production and extraction of shale gas and associated fluids, which would lower the pressure in the hydrofractured zone and decrease the initial upward mobility of solutes, as well as the duration of overpressured conditions that drive upward fluid flow.

[46] 10. A change in the initial distribution of salinity could impact the time of migration of contaminants, as a lower density would enhance upwards flow and a higher density would decrease it.

[47] 11. Recharge rates used in this study are lower by approximately an order of magnitude compared to the ones present in the St. Lawrence lowlands, and may be more representative of more arid regions. A higher recharge rate would lower the concentrations of solutes in the aquifer, but would not impact the results in terms of solute mass fluxes reaching the freshwater aquifer.

[48] Long-term risk of groundwater contamination due to migration via faults raises the question of the appropriate time frame of water management, especially when dealing with large-scale industrial activities with potential cumulative effects such as shale gas development. The time frame of water resources management is typically 5–20 years [Gleeson et al., 2012], which may be appropriate for surface water systems which have short residence times. However, groundwater can have very long residence times. The global average groundwater residence time is estimated to be 1400 years [UNESCO, 1978]. Geological repositories for high-level nuclear waste are designed to limit escape to the biosphere tens to hundreds of thousands of years. A multigenerational time horizon of 50–100 years for the management of groundwater has been proposed by Gleeson et al. [2012], so that the impacts of a broad range of hydrogeological conditions can be adequately built into effective management and policy plans. Lenton [2011] suggested an even longer time horizon of 1000 years as a full, ethical time horizon for which the

human impact on biophysical systems should be evaluated. Monitoring over this time-frame and the precautionary principle [Norton, 2005] would be especially appropriate for deep sedimentary basins, such as those where shale gas is found, where at least some part of the exploited groundwater resources have a very long residence time and the impact of contamination at depth is likely irreversible.

6. Conclusions

[49] Publically available data of shale gas basins and hydraulic fracturing operations were systematically compiled to serve as a basis for the development of a two-dimensional model of a generic, regional, faulted sedimentary basin having an active groundwater flow zone at its upper limit. Hydraulic fracturing was represented in the model by a change in permeability and simulations investigated its potential impact on fluid flow and contaminant transport from the shale formation to a shallow aquifer along a fault zone. A sensitivity analysis was carried out to identify which parameters control the contaminant transport potential.

[50] Contamination from the target shale unit to shallow aquifers due to hydraulic fracturing is often neglected [Arthur et al., 2008; Zoback et al., 2010; BAPE, 2011; Howarth et al., 2011; Osborn et al., 2011; EPA, 2012]. However, numerical simulation results from this study show that migration of contaminants along a fault zone to shallow depths could occur under some specific conditions. Although simulation results show that contamination occurs on long timescales (ffi1000 years), this scenario of contamination should not be ignored, but should rather be further investigated. This study raises the question of the time frame of water resources management and the ethical time frame to be considered when actions are taken to prevent groundwater contamination. Results show that the most important parameter controlling contaminant transport potential is the location of the hydro-fractured zone relative to the fault zone and fracturing of the top of the shale, suggesting that contamination via permeable faults could be prevented if regional faults are mapped and avoided. Upward migration of contaminants also has to be driven by an overpressure in the shale unit. Basin and fault parameters, such as matrix and fault permeability in the overlying sediments also impact migration potential.

[51] Further work is needed to assess potential upwards migration along a fault zone following gas shale hydraulic fracturing. Numerical simulations, including multiphase flow, would allow a better description of hydrological processes in the shale, fault, and overlying formations. Additional data from hydraulic fracturing operations, such as pressure regime and variation in permeability during hydraulic fracturing, should be recorded and made publically available as they would be highly valuable in order to develop numerical models that are as realistic as possible. Before hydraulic fracturing operations, hydrogeological properties of the subsurface and faults location, density and hydraulic properties should be analyzed in order to evaluate the risk of shallow groundwater contamination by migration via fault zones. The precautionary principle [Norton, 2005] suggests hydraulic fracturing should not be carried out near potentially conductive faults, and that regulations should consider monitoring the contamination potential due to migration via faults over longer timespans than water resources management typically consider.

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Zoback, M. D. (2007), Reservoir Geomechanics, 449 pp., Cambridge Univ. Press, N. Y.

Zoback, M., S. Kitasei, and B. Copithorne (2010), Addressing the environmental risks from shale gas development, Report, 365 pp, Worldwatch Institute, U.S. Dep. of Energy, Washington, D. C.

To: Ridley, Caroline[Ridley.Caroline@epa.gov]
From: Jonathan Koplos
Sent: Mon 2/23/2015 6:44:39 PM
Subject: RE: Status of HFDWA extraneous bits- front matter and appendices

Ex. 5

From: Ridley, Caroline [mailto:Ridley.Caroline@epa.gov]
Sent: Monday, February 23, 2015 12:44 PM
To: Anna Weber
Cc: Jonathan Koplos
Subject: RE: Status of HFDWA extraneous bits- front matter and appendices

Ex. 5

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment
~~~~~~

Office: (703) 347-8506 Ex. 6

From: Anna Weber Ex. 4
Sent: Monday, February 23, 2015 11:59 AM
To: Ridley, Caroline; Frithsen, Jeff
Cc: Jonathan.Koplos Ex. 4 LeDuc, Stephen
Subject: RE: Status of HFDWA extraneous bits- front matter and appendices

We can adjust the TOC however you want, Caroline! That's not a problem.

From: Ridley, Caroline [mailto:Ridley.Caroline@epa.gov]
Sent: Monday, February 23, 2015 11:38 AM
To: Frithsen, Jeff
Cc: Jonathan Koplos; LeDuc, Stephen; Anna Weber
Subject: RE: Status of HFDWA extraneous bits- front matter and appendices

Thanks, Jeff.

Ex. 5

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist
~~~~~~

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 Ex. 6

From: Frithsen, Jeff
Sent: Monday, February 23, 2015 11:04 AM
To: Ridley, Caroline
Cc: Jonathan.Koplos Ex. 4 LeDuc, Stephen
Subject: RE: Status of HFDWA extraneous bits- front matter and appendices

Ex. 5

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Ridley, Caroline
Sent: Monday, February 23, 2015 10:41 AM
To: Frithsen, Jeff
Cc: Jonathan.Koplos Ex. 4 LeDuc, Stephen
Subject: RE: Status of HFDWA extraneous bits- front matter and appendices

Ex. 5

Thanks,

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 Ex. 6

From: Ridley, Caroline
Sent: Friday, February 13, 2015 4:49 PM
To: Burden, Susan; Frithsen, Jeff; LeDuc, Stephen
Cc: Jonathan Koplos
Subject: Status of HFDWA extraneous bits- front matter and appendices

All,

Ex. 5

Have a good long weekend!

Caroline

Ex. 5
~~~~~~

Ex. 5

Ex. 5

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 Ex. 6
~~~~~~

To: Knightes, Chris[Knightes.Chris@epa.gov]; Jonathan.Koplos Ex. 4 Ridley, Caroline[Ridley.Caroline@epa.gov]
Cc: Williams, Larke[Williams.Larke@epa.gov]; Daiss, Rebecca[Daiss.Rebecca@epa.gov]; Singer, Alison[Singer.Alison@epa.gov]
From: Krissy Downing
Sent: Thur 2/19/2015 3:00:46 PM
Subject: Re: latest version of chem mixing figure

Ex. 5

Best,

Krissy

Krissy Downing | Senior Designer
The Cadmus Group, Inc.
Seattle, WA | Phone: 202-386-1854

From: Knightes, Chris <Knightes.Chris@epa.gov>
Sent: Thursday, February 19, 2015 6:54 AM
To: Jonathan Koplos; Ridley, Caroline
Cc: Williams, Larke; Daiss, Rebecca; Singer, Alison; Krissy Downing
Subject: RE: latest version of chem mixing figure

Hey Jonathan,

Ex. 5

Thanks,

Chris

From: Jonathan Koplos Ex. 4
Sent: Monday, February 16, 2015 9:14 AM
To: Ridley, Caroline; Knightes, Chris
Cc: Williams, Larke; Daiss, Rebecca; Singer, Alison; Krissy Downing

Subject: FW: latest version of chem mixing figure

Ex. 5

Jonathan

Jonathan Koplos, Ph.D.

The Cadmus Group, Inc.

100 5th Avenue, Suite 100

Waltham, MA 02451

Ph. 617-673-7184

Ex. 6

www.cadmusgroup.com

From: Knightes, Chris [mailto:Knightes.Chris@epa.gov]
Sent: Tuesday, February 10, 2015 11:14 AM
To: Jonathan Koplos; Williams, Larke; Daiss, Rebecca; Singer, Alison
Cc: Ridley, Caroline; Krissy Downing
Subject: RE: latest version of chem mixing figure

Hey Jonathan,

Ex. 5

Ex. 5

Thanks!

From: Jonathan Koplos Ex. 4
Sent: Sunday, February 08, 2015 10:16 PM
To: Knightes, Chris; Williams, Larke; Daiss, Rebecca

Cc: Ridley, Caroline; Krissy Downing
Subject: latest version of chem mixing figure

Chris, Larke, and Becky,

Ex. 5

Jonathan

Follow us on social media:

Follow us on social media:

To: Ridley, Caroline[Ridley.Caroline@epa.gov]; Cluff, Maryam[Cluff.Maryam@epa.gov]; Lowrance, Richard[Lowrance.Richard@epa.gov]; Weaver, Jim[Weaver.Jim@epa.gov]
From: Jim Weaver
Sent: Thur 2/19/2015 3:18:08 AM
Subject: Chapter 7

Ex. 5

I'm sending this from my home email, because the EPA remote access email appears not to be working at the moment.

-Jim

To: Ridley, Caroline[Ridley.Caroline@epa.gov]
Cc: Shari.Ring Ex. 4 ; Deniz (Inci) Demirkanli Ex. 4 ; Ken Klewicki Ex. 4
From: Anna Weber
Sent: Wed 2/18/2015 5:23:39 PM
Subject: Reference QA sheet for Chapter 6

Ex. 5

Hi Caroline,

Ex. 5

Thanks,

Anna

Anna A. Weber | Associate

The Cadmus Group, Inc.

1555 Wilson Blvd., Suite 300 | Arlington, VA 22209

(703) 247-6172 | www.cadmusgroup.com

Follow us on social media:

To: Ridley, Caroline[Ridley.Caroline@epa.gov]
Cc: Anna Weber Ex. 4
From: Jonathan Koplos
Sent: Wed 2/18/2015 3:57:13 PM
Subject: RE: Chapter 2 here, Chapter 3 hopefully this evening

Ex. 5

Anna, I'll give you a call.

From: Ridley, Caroline [mailto:Ridley.Caroline@epa.gov]
Sent: Wednesday, February 18, 2015 10:24 AM
To: Jonathan Koplos
Cc: Anna Weber
Subject: FW: Chapter 2 here, Chapter 3 hopefully this evening

Ex. 5

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 Ex. 6
~~~~~~

From: Ridley, Caroline
Sent: Friday, January 30, 2015 12:02 PM
To: 'Jonathan Koplos'
Subject: RE: Chapter 2 here, Chapter 3 hopefully this evening

Jonathan,

Ex. 5

Thanks,

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 Ex. 6
~~~~~~

From: Jonathan Koplos Ex. 4
Sent: Saturday, January 24, 2015 5:50 AM
To: Ridley, Caroline
Subject: RE: Chapter 2 here, Chapter 3 hopefully this evening

Ex. 5

Jonathan

From: Ridley, Caroline [mailto:Ridley.Caroline@epa.gov]
Sent: Friday, January 23, 2015 8:21 PM
To: Jonathan Koplos
Subject: RE: Chapter 2 here, Chapter 3 hopefully this evening

Thanks, Jonathan.

Ex. 5

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 Ex. 6

From: Jonathan Koplos Ex. 4
Sent: Friday, January 23, 2015 4:52 PM
To: Ridley, Caroline
Subject: Chapter 2 here, Chapter 3 hopefully this evening

Hi Caroline,

Here is Chapter 2. In the interest of time I am sending it along although I think it needs a tad more work just to make it look better. Somehow, it's not doing it for me. Sorry, I ran out of
~~~~~~

Ex. 5

Ex. 6

Jonathan

Jonathan Koplos, Ph.D.

The Cadmus Group, Inc.

100 5th Avenue, Suite 100

Waltham, MA 02451

Ph. 617-673-7184

Ex. 6

www.cadmusgroup.com

Follow us on social media:

To: Ridley, Caroline[Ridley.Caroline@epa.gov]
From: Frithsen, Jeff
Sent: Wed 2/18/2015 3:58:09 AM
Subject: FW: HFDWA: Initial Feedback on draft Chapters

Ex. 5

Thanks.

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Frithsen, Jeff
Sent: Tuesday, February 17, 2015 10:54 PM
To: Burden, Susan; Frithsen, Jeff; LeDuc, Stephen; Ridley, Caroline; Burgoon, Lyle; Cluff, Maryam; Fleming, Megan; Impellitteri, Christopher; Jonathan.Koplos Ex. 4 Knightes, Chris; MaryEllen Tuccillo; Shari.Ring Ex. 4 Stanek, John; Weaver, Jim; Yohannes, Lia
Subject: HFDWA: Initial Feedback on draft Chapters

Ex. 5

Ex. 5

Jeff

Jeffrey B. Frithsen, Ph.D.

National Center for Environmental Assessment

Office of Research and Development

U.S. Environmental Protection Agency

1200 Pennsylvania Avenue, SW (8623-P)

Washington, DC 20460

703-347-8623 (office phone)

Physical Office Address/Overnight Deliveries

Two Potomac Yard (North Building), Room N-7741

2733 South Crystal Drive, Arlington, VA 22202

To: Ridley, Caroline[Ridley.Caroline@epa.gov]
Cc: Knightes, Chris[Knightes.Chris@epa.gov]
From: Jonathan Koplos
Sent: Wed 2/18/2015 12:31:37 AM
Subject: 17Feb2015 DRAFTS of Chapter 2 and Chapter 6

Ex. 5

Hi Caroline and Chris,

Latest versions of Chapters 2 and 6 attached.

Ex. 5

Ex. 5

Jonathan

Jonathan Koplos, Ph.D.

The Cadmus Group, Inc.

100 5th Avenue, Suite 100

Waltham, MA 02451

Ph. 617-673-7184

Ex. 4

www.cadmusgroup.com

Follow us on social media:

To: Ridley, Caroline[Ridley.Caroline@epa.gov]
Cc: Jonathan.Koplos Ex. 4
From: Yohannes, Lia
Sent: Tue 2/17/2015 7:50:02 PM
Subject: Re: Snow day in DC, but available as much as possible

Ex. 5

Hi Jonathan,

Ex. 5

Thanks,

Lia

Liabeth Yohannes

Office of Research and Development

U.S. Environmental Protection Agency

Email: yohannes.lia@epa.gov

Phone: (202) 564-6755

From: Ridley, Caroline
Sent: Tuesday, February 17, 2015 10:48 AM
To: Yohannes, Lia
Cc: Jonathan.Koplos Ex. 4
Subject: FW: Snow day in DC, but available as much as possible

Ex. 5

Ex. 5

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 Ex. 6

From: Jonathan Koplos Ex. 4
Sent: Tuesday, February 17, 2015 9:59 AM
To: Ridley, Caroline; Shari.Ring Ex. 4 Weaver, Jim; Fleming, Megan; Stanek, John; Anna Weber; Knightes, Chris; Burden, Susan; Frithsen, Jeff; LeDuc, Stephen
Subject: RE: Snow day in DC, but available as much as possible

Ex. 5
~~~~~~

Ex. 5

Jonathan

Jonathan Koplos, Ph.D.

The Cadmus Group, Inc.

100 5th Avenue, Suite 100

Waltham, MA 02451

Ph. 617-673-7184

Ex. 4

www.cadmusgroup.com

From: Ridley, Caroline [mailto:Ridley.Caroline@epa.gov]
Sent: Tuesday, February 17, 2015 9:10 AM
To: Jonathan Koplos; Shari Ring; Weaver, Jim; Fleming, Megan; Stanek, John; Anna Weber; Knightes, Chris; Burden, Susan; Frithsen, Jeff; LeDuc, Stephen
Subject: Snow day in DC, but available as much as possible

Hi, all,

Ex. 5

Ex. 6

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 Ex. 6
~~~~~~

To: Ridley, Caroline[Ridley.Caroline@epa.gov]
Cc: Deniz (Inci) Demirkanli[Ex. 4] Anna Weber[Ex. 4] Ken Klewicki[Ex. 4] Jonathan.Koplos[Ex. 4]
From: Shari Ring
Sent: Mon 2/16/2015 12:33:01 PM
Subject: Chapter 6

Ex. 5

Hi Caroline,

Ex. 5

Please let me know if you have any questions. I'll be in the office most of today (Monday).

Shari Ring

The Cadmus Group, Inc.

703.247.6159

Follow us on social media:

To: Norman Ellstrand **Ex. 6**
From: Ridley, Caroline
Sent: Tue 7/14/2015 7:17:47 PM
Subject: Link to EPA's hydraulic fracturing assessment

Ex. 5

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays) **Ex. 6**
~~~~~~

To: Itkin, Cheryl[Itkin.Cheryl@epa.gov]
From: Ridley, Caroline
Sent: Tue 6/23/2015 3:51:41 PM
Subject: FW: TD under WA 7-83: Documentation of QA conducted PREVIEW 19June2015

Ex. 5

Cheryl,

Ex. 5

Thanks,

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): Ex. 6

From: Jonathan Koplos Ex. 4
Sent: Friday, June 19, 2015 5:40 PM
To: Ridley, Caroline; LeDuc, Stephen
Cc: MaryEllen.Tuccillo Ex. 4
Subject: RE: TD under WA 7-83: Documentation of QA conducted PREVIEW 19June2015

Hi Caroline and Steve,
~~~~~~

Ex. 5

Jonathan

Jonathan Koplos, Ph.D.

The Cadmus Group, Inc.

100 5th Avenue, Suite 100

Waltham, MA 02451

Ex. 6

www.cadmusgroup.com

From: Ridley, Caroline [mailto:Ridley.Caroline@epa.gov]
Sent: Tuesday, June 02, 2015 3:51 PM
To: Jonathan Koplos
Cc: Parrotta, Nancy; Reinhart, Donna; LeDuc, Stephen
Subject: TD under WA 7-83: Documentation of QA conducted

Jonathan,

Ex. 5

Thank you,

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and Ex. 6
~~~~~~

To: Johnson, Maureen[Johnson.Maureen@epa.gov]
From: Ridley, Caroline
Sent: Mon 6/8/2015 2:57:21 PM
Subject: FW: TD under WA 7-83: Spreadsheet of alt text_8June2015_Draft

Ex. 5

Hi, Maureen,

Ex. 5

Thanks,

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 Ex. 6

From: Jonathan Koplos Ex. 4
Sent: Monday, June 08, 2015 9:21 AM
To: Ridley, Caroline
Subject: FW: TD under WA 7-83: Spreadsheet of alt text_8June2015_Draft

Good morning, Caroline.
~~~~~~

Ex. 5

Jonathan

To: Frithsen, Jeff[Frithsen.Jeff@epa.gov]
From: Ridley, Caroline
Sent: Fri 6/5/2015 7:19:31 PM
Subject: RE: HF Monthly Call with Agency Representatives

Ex. 5

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and Ex. 6

From: Frithsen, Jeff
Sent: Friday, June 05, 2015 1:52 PM
To: Ridley, Caroline
Subject: HF Monthly Call with Agency Representatives

Caroline:

Ex. 5

Jeff
~~~~~~

Jeffrey B. Frithsen, Ph.D.

National Center for Environmental Assessment

Office of Research and Development

U.S. Environmental Protection Agency

1200 Pennsylvania Avenue, SW (8623-P)

Washington, DC 20460

703-347-8623 (office phone)

Physical Office Address/Overnight Deliveries

Two Potomac Yard (North Building), Room N-7741

2733 South Crystal Drive, Arlington, VA 22202

To: Sanzone, Stephanie[Sanzone.Stephanie@epa.gov]
Cc: Frithsen, Jeff[Frithsen.Jeff@epa.gov]; Johnson, Maureen[Johnson.Maureen@epa.gov]
From: Ridley, Caroline
Sent: Thur 6/4/2015 1:21:28 PM
Subject: New HF ES cover with document

Ex. 5

Stephanie,

Ex. 5

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and **Ex. 6**
~~~~~~

To: Solomon, Sarah[Solomon.Sarah@epa.gov]
From: Ridley, Caroline
Sent: Wed 6/3/2015 5:32:21 PM
Subject: RE: Folder

Ex. 5

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and **Ex. 6**

From: Ridley, Caroline
Sent: Wednesday, June 03, 2015 1:24 PM
To: Solomon, Sarah
Subject: Folder

Can you access?

Ex. 5

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and Ex. 6

To: Frithsen, Jeff[Frithsen.Jeff@epa.gov]
From: Ridley, Caroline
Sent: Wed 6/3/2015 2:37:27 PM
Subject: Locations of exemplified vulnerabilities

Jeff,

Ex. 5

Ex. 5

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): Ex. 6
~~~~~~

To: Johnson, Maureen[Johnson.Maureen@epa.gov]
From: Ridley, Caroline
Sent: Thur 5/14/2015 6:23:04 PM
Subject: RE: 508-ing of the HF document

Ex. 5

~~~~~~

Caroline E. Ridley, PhD
Ecologist
US Environmental Protection Agency
Office of Research and Development
National Center for Environmental Assessment
Office: (703) 347-8506 and AWL (Fridays): (703) 362-5955

-----Original Message-----
From: Johnson, Maureen
Sent: Thursday, May 14, 2015 1:19 PM
To: Ridley, Caroline
Subject: Re: 508-ing of the HF document

Hi Caroline,

Ex. 5

> Thanks!
> Caroline
>
> ~~~~~~
> Caroline E. Ridley, PhD
> Ecologist
> US Environmental Protection Agency
> Office of Research and Development
> National Center for Environmental Assessment
~~~~~~

> Office: (703) 347-8506 Ex. 6
>

Ex. 5

To: Frithsen, Jeff[Frithsen.Jeff@epa.gov]
From: Ridley, Caroline
Sent: Fri 5/8/2015 9:54:31 PM
Subject: FW: May 4 version of Chapter 2

Ex. 5

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and Ex. 6

From: Ridley, Caroline
Sent: Friday, May 08, 2015 9:32 AM
To: 'Jonathan Koplos'
Cc: Anna Weber
Subject: RE: May 4 version of Chapter 2

Ex. 5

Caroline
~~~~~~

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and Ex. 6

From: Jonathan Koplos Ex. 4
Sent: Thursday, May 07, 2015 11:56 PM
To: Ridley, Caroline
Cc: Anna Weber
Subject: RE: May 4 version of Chapter 2

Thank you.

Talk tomorrow.

From: Ridley, Caroline [mailto:Ridley.Caroline@epa.gov]
Sent: Thursday, May 07, 2015 9:19 PM
To: Jonathan Koplos
Cc: Anna Weber
Subject: RE: May 4 version of Chapter 2

Jonathan,

Ex. 5

Will send an invite for tomorrow morning.
~~~~~~

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and Ex. 6

From: Jonathan Koplos Ex. 4
Sent: Thursday, May 07, 2015 5:24 PM
To: Ridley, Caroline
Cc: Anna Weber
Subject: RE: May 4 version of Chapter 2

Ex. 5

Any time tomorrow in your time frame works for me.

From: Ridley, Caroline [mailto:Ridley.Caroline@epa.gov]
Sent: Thursday, May 07, 2015 4:17 PM
To: Jonathan Koplos
Cc: Anna Weber
Subject: RE: May 4 version of Chapter 2

Ex. 5
~~~~~~

Ex. 5

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and Ex. 6

From: Jonathan Koplos Ex. 4
Sent: Thursday, May 07, 2015 3:45 PM
To: Ridley, Caroline
Cc: Anna Weber
Subject: RE: May 4 version of Chapter 2

Ex. 5

Jonathan
~~~~~~

Ex. 5

From: Ridley, Caroline [mailto:Ridley.Caroline@epa.gov]
Sent: Thursday, May 07, 2015 2:29 PM
To: Jonathan Koplos
Cc: Anna Weber
Subject: RE: May 4 version of Chapter 2

Ex. 5

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and Ex. 6

From: Ridley, Caroline
Sent: Tuesday, May 05, 2015 11:29 AM
To: 'Jonathan Koplos'
Cc: Anna Weber
Subject: RE: May 4 version of Chapter 2
~~~~~~

Jonathan,

Ex. 5

Thanks!

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): (703) 362-5955
~~~~~~

From: Jonathan Koplos Ex. 4
Sent: Monday, May 04, 2015 1:59 PM
To: Ridley, Caroline
Cc: Anna Weber
Subject: May 4 version of Chapter 2

Hi Caroline,

Ex. 5

Jonathan

Ex. 5

Jonathan Koplos, Ph.D.

The Cadmus Group, Inc.

100 5th Avenue, Suite 100

Waltham, MA 02451

Ph. 617-673-7184

Ex. 6

www.cadmusgroup.com

Follow us on social media:

To: Meacham, Connie[Meacham.Connie@epa.gov]; Jones, Ryan[Jones.Ryan@epa.gov]
Cc: Anna Weber Ex. 6 Weaver, Jim[Weaver.Jim@epa.gov]
From: Ridley, Caroline
Sent: Fri 5/8/2015 1:11:48 AM
Subject: FW: more new references for HF project page

Ex. 5

Connie,

Ex. 5

Thank you!

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and Ex. 6

From: Weaver, Jim
Sent: Thursday, May 07, 2015 6:07 PM
To: Ridley, Caroline
Subject: more new references

Bethke, C.M., Yeakel, S., 2014,The Geochemist's Workbench, Release 10.0, GWB Essentials Guide, Aqueous Solutions, LLC, Champaign, Illinois

Ex. 5
~~~~~~

Ex. 5

Jim Weaver, Ph. D. | Research Hydrologist

U.S. Environmental Protection Agency | National Risk Management Research Laboratory | Ground Water and Ecosystems Restoration Division

919 Kerr Research Dr | Ada, Oklahoma 74820 | 580-436-8550 | weaver.jim@epa.gov

The Geochemist's Workbench®

Release 10.0

GWB Essentials Guide

The Geochemist's Workbench®

Release 10.0

GWB Essentials Guide

Craig M. Bethke
Sharon Yeakel
Aqueous Solutions, LLC
Champaign, Illinois

Printed November 11, 2014

The GWB software was originally developed by the students, staff, and faculty of the Hydrogeology Program in the Department of Geology at the University of Illinois Urbana-Champaign. The package is currently developed and maintained by Aqueous Solutions LLC at the University of Illinois Research Park.

Address inquiries to

Aqueous Solutions LLC
301 North Neil Street, Suite 400
Champaign, IL 61820 USA

Contents

Chapter List

Contents

Contents

Origin of the programs

The GWB package was originally developed at the Department of Geology of the University of Illinois at Urbana-Champaign over a period of more than twenty years, under the sponsorship of a consortium of companies and government laboratories. The members of the consortium, past and present, include:

Amoco Production Company
Arco Oil and Gas Company
Chevron Petroleum Technology Corporation
ConocoPhillips Company
ExxonMobil Upstream Research Company
Hewlett Packard, Incorporated
Idaho National Engineering Lab
Japan National Oil Corporation
Lawrence Livermore National Laboratory
Marathon Oil Company
Mobil Research and Development Corporation
Sandia National Laboratories
SCK-CEN (Belgian nuclear authority)
SiliconGraphics Computer Systems
Texaco, Incorporated
Union Oil Company of California
United States Geological Survey

The original GWB package was written by Craig Bethke with the assistance of Ming-Kuo Lee and Jeffrey Biesiadecki of the Hydrogeology Program in the Department of Geology, University of Illinois at Urbana-Champaign. The GWB is currentlydevelopedandsupportedbyAqueousSolutionsLLC ,locatedintheResearch Park at the University of Illinois.

A number of programmers in the Hydrogeology Program, including Rick Hedin, Peter Berger, Tren Haselton, Ester Soriano, David Solt, and Lalita Kalita helped develop the user interface. Brian Healy and Walter Kreiling developed a library used by the programs to produce graphical images on various output devices, and David Solt, Tren Haselton, Changlin Huang, Ester Soriano, Xiang Zhao, and Kevin Gorczowski have updated and eventually replaced this library over the years. J.K. Bohlke, Eric Daniels, and Ming-Kuo Lee compiled the dataset of isotope fractionation factors;Daniel Saalfeld helped translatethermodynamic datasets totheGWBformat;

Amy Berger helped develop the surface complexation model; Qusheng Jin helped implement the redox kinetics and microbiological features; and Jungho Park created the GWB Symbol font and helped develop React's ability to use custom rate laws. Peter Berger, Rick Hedin, Phil Parker, Dan Saalfeld, and Sharon Yeakel developed the active graphics facilities and other features of release 7.0; Sharon Yeakel helped prepare documentation for the release. Phil Parker worked on developing the multithreaded versions of X1t and X2t for release 8.0, and Dan Saalfeld, Sharon Yeakel, and Jesse Luehrs developed program GSS and other features of the release. Dan Saalfeld, Sharon Yeakel, and Jesse Luehrs, with the assistance of Brian Farrell, developed release 9.0. Dan Saalfeld, Sharon Yeakel, Brian Farrell, Bryan Plummer, and Steven Canning developed release 10.0.

The software authors appreciate the assistance of more people than we can remember who over the years helped with software development and testing. These people include Theresa Beckman, Bill Bourcier, Pat Brady, Ten-hung Chu, David Finkelstein, Ted Flynn, Annette Fugl, Oscar Garcia Cabrejo, Man Jae Kwon, Matt Kyrias, Kurt Larson, Meng Lei, Melinda Legg, Gordon Madise, Chuck Norris, Hernán Quinodoz, Derik Strattan, and Melinda Tidrick. We also thank the many students and users who have suggested improvements to the codes and documentation.

Introduction

The Geochemist's Workbench is a set of software tools for manipulating chemical reactions, calculating stability diagrams and the equilibrium states of natural waters, tracing reaction processes, modeling reactive transport, plotting the results of these calculations, and storing the related data. The Workbench, designed for personal computers running MS Windows, is distributed in three packages:

- GWB Essentials contains tools for balancing reactions, calculating activity diagrams, computing speciation in aqueous solutions, plotting the results of these calculations, and storing the related data.
- GWB Standard contains these tools as well as a program for modeling reaction processes.
- GWB Professional includes all the programs in the Standard Release, plus programs for modeling reactive transport in one and two dimensions, and for plotting modeling results.

The GWB Essentials release consists of seven programs:

- GSS stores analyte and sample data in a spreadsheet specially developed to work with the GWB set of software tools.
- Rxn automatically balances chemical reactions, calculates equilibrium constants and equations, and solves for the temperatures at which reactions are in equilibrium.
- Act2 calculates and plots stability diagrams on activity and fugacity axes. It can also project the traces of reaction paths calculated using the React program.

  Tact calculates and plots temperature-activity and temperature-fugacity diagrams and projects the traces of reaction paths.

- SpecE8 calculates species distributions in aqueous solutions and computes mineral saturations and gas fugacities. SpecE8 can account for sorption of species onto mineral surfaces according to a variety of methods, including surface complexation and ion exchange.
- Gtplot graphs SpecE8 results and GSS datasets, including on xy plots, ternary, Piper, Durov, and Stiff diagrams.
- TEdit displays, modifies, and creates the thermodynamic and surface reaction datasets used by the various GWB applications.

The GWB Standard release also includes the program:

- React in addition to having the capabilities of SpecE8, traces reaction paths involving fluids, minerals, and gases. React can also predict the fractionation of stable isotopes during reaction processes. The simulation results can be rendered with program Gtplot.

The GWB Professional release contains the additional programs:

- X1t simulates reactive transport in one dimensional systems. The program has all of React's geochemical modeling capabilities, except isotope fractionation, coupled with groundwater flow and transport.
- X2t simulates reactive transport in two-dimensional systems.
- Xtplot plots in map view and as xy plots the results of reactive transport simulations made using X1t and X2t.

Each of the programs operates in a similar fashion, so once you learn to use one, you will find the others easy to work with.

1.1 GWB Documentation

Depending on the package, the GWB comes with a set of User's Guides accessible as pdf files from the Help pulldown of any of the programs, and also available in printed form:

GWB Essentials Guide — A guide to GSS, Rxn, Act2, Tact, SpecE8, Gtplot, and TEdit (this document).

- Reaction Modeling Guide — Information on reaction modeling using React, and using Gtplot to render simulation results.
- Reactive Transport Modeling Guide — A guide to reactive transport modeling with X1t, X2t, and Xtplot.
- Reference Manual — A comprehensive guide to commands for the GWB programs, the format of the thermodynamic datasets, and so on.

A considerable amount of information, including a large number of fully worked examples, is available in the Geochemical and Biogeochemical Reaction Modeling text, available from Cambridge University Press or book sellers such as Amazon.

1.2 On-line tutorials

The GWB website – www.gwb.com – contains a variety of step-by-step tutorials showing how to use the GWB software package. The website also contains a large number of diagrams and movies showing the results of GWBcalc ulations. By clicking the icons next toeach case, you can download the input scripts used toconfigure the calculation, or start the appropriate GWB application, configured and ready to run.

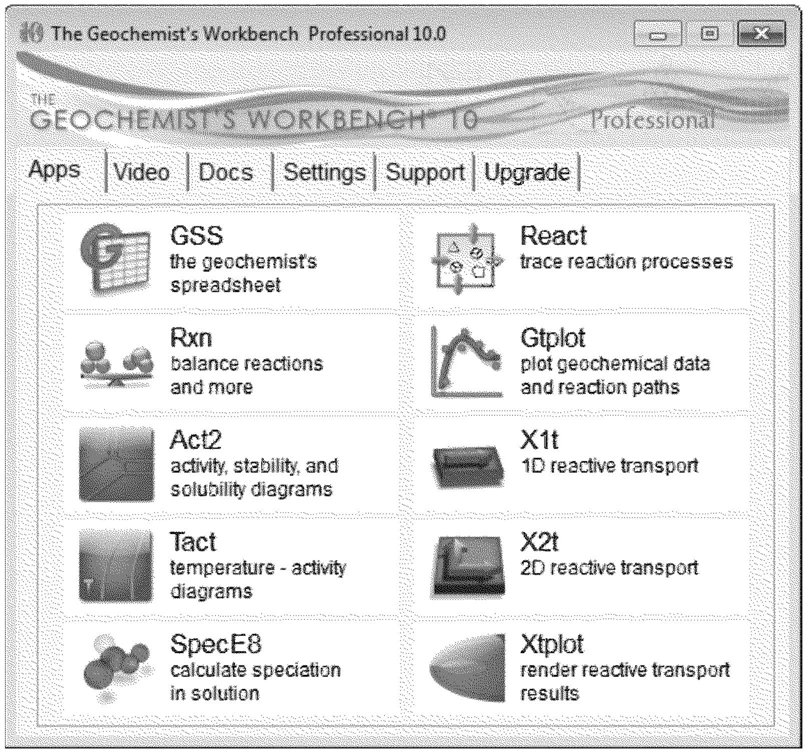
The GWB Youtube channel – www.youtube.com/user/GeochemistsWorkbench – contains a number of instructional video clips that will quickly and efficiently help you become expert in using the software.

1.3 GWB dashboard

The GWB dashboard is the platform from which you run the GWB programs, access documentation, find on-line video tutorials, activate and configure the software, and upgrade your software installation.

YoustarttheGWBdashboard from the Start button onyour Windows 7desktop, or the Start charm (touch Win+q) in Windows 8. Select The Geochemist's Workbench 10.0 menu, which brings up the GWB dashboard.

Take a moment to explore each of the tabs along the top of the window. You launch the various GWB programs from the Apps pane. The Video and Docs panes take you to video tutorials and options for printed documentation. You configure the software on the Settings pane, and the Support pane provides tools to activate the software, edit thermo datasets, and obtain user support. The Upgrade pane shows options for upgrading your software license. The workbench looks like:



You start the individual GWB programs in any of several ways. You can click on the program's icon in the Apps pane, open (e.g., double-click on) a GWB input file from Windows, or simply drag an input file into the GWB dashboard.

1.4 GWB modeling programs

When Rxn, Act2, Tact, SpecE8, React, X1t, and X2t start, they appear as a window containing several panes and a menubar. Program Rxn's window, for example, is shown in Figure 1.1.

It contains three panes:

- The Basis pane, where you can set the most important calculation constraints, as described below.
- The Command pane, where you can type Rxn commands.

  The Results pane, where you view calculation results.

You can detach each pane by dragging the pane title to the desktop with the left-mouse button. In this way you can arrange and size the panes individually. The

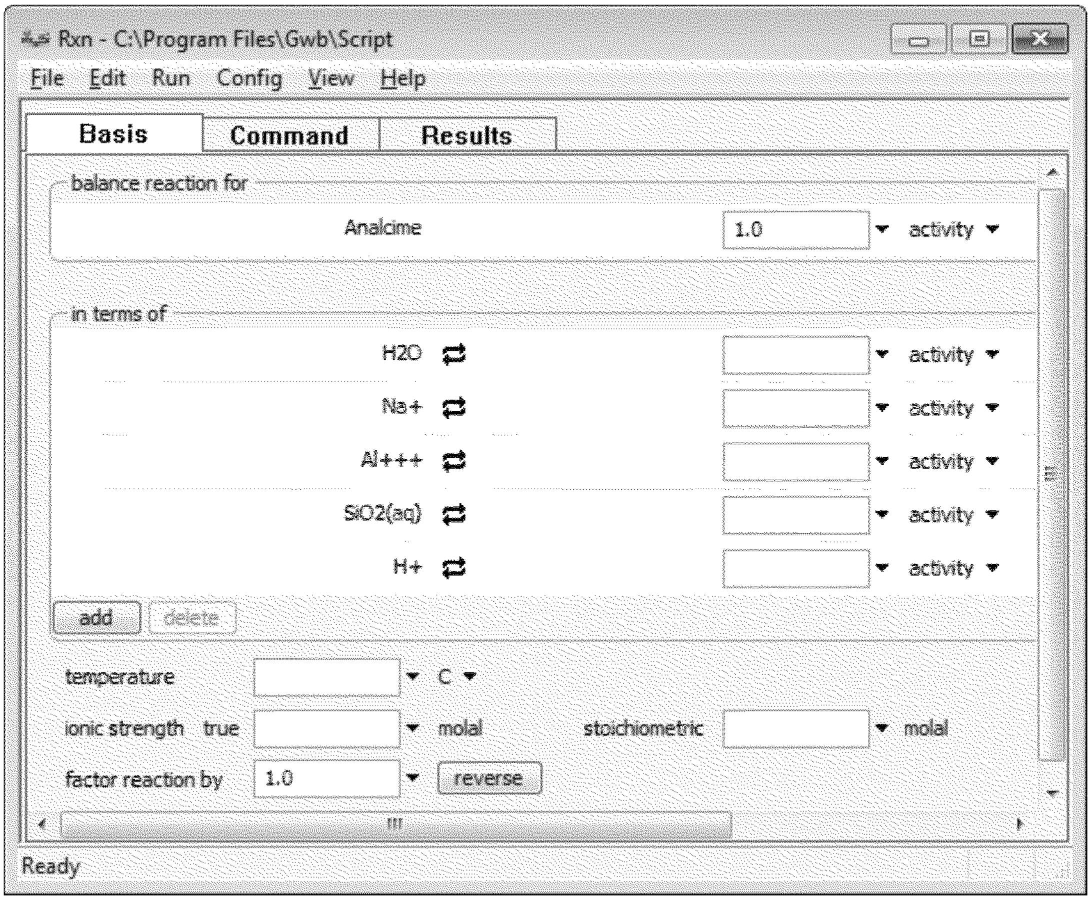


Figure 1.1 The window for program Rxn, showing the menubar and tabs for the three panes. You can type commands in the Command pane, or use the mouse to configure the program on the Basis pane, or by selecting options and dialog boxes from the menubar. Calculation results appear in the Results pane.

window also contains a menubar, from which you can select a number of options and display a variety of dialog boxes.

When programs Rxn, Act2, Tact, SpecE8, React, X1t, and X2t start, they assume the working directory from the previous run. The programs write output into this directory and look there for input files. You can change the working directory at any time by selecting File ! Working Directory or Ctrl+Shift+W; the current setting is displayed on the window frame (see Figure 1.1).

Once you have configured a calculation, you generate the calculation results by selecting Run ! Go or, on the Results output pane, pressing the Run button (or in Act2 and Tact the Update Plot button). Once you have viewed the calculation results, you can move to another pane or select options from the menubar to modify the program's configuration.

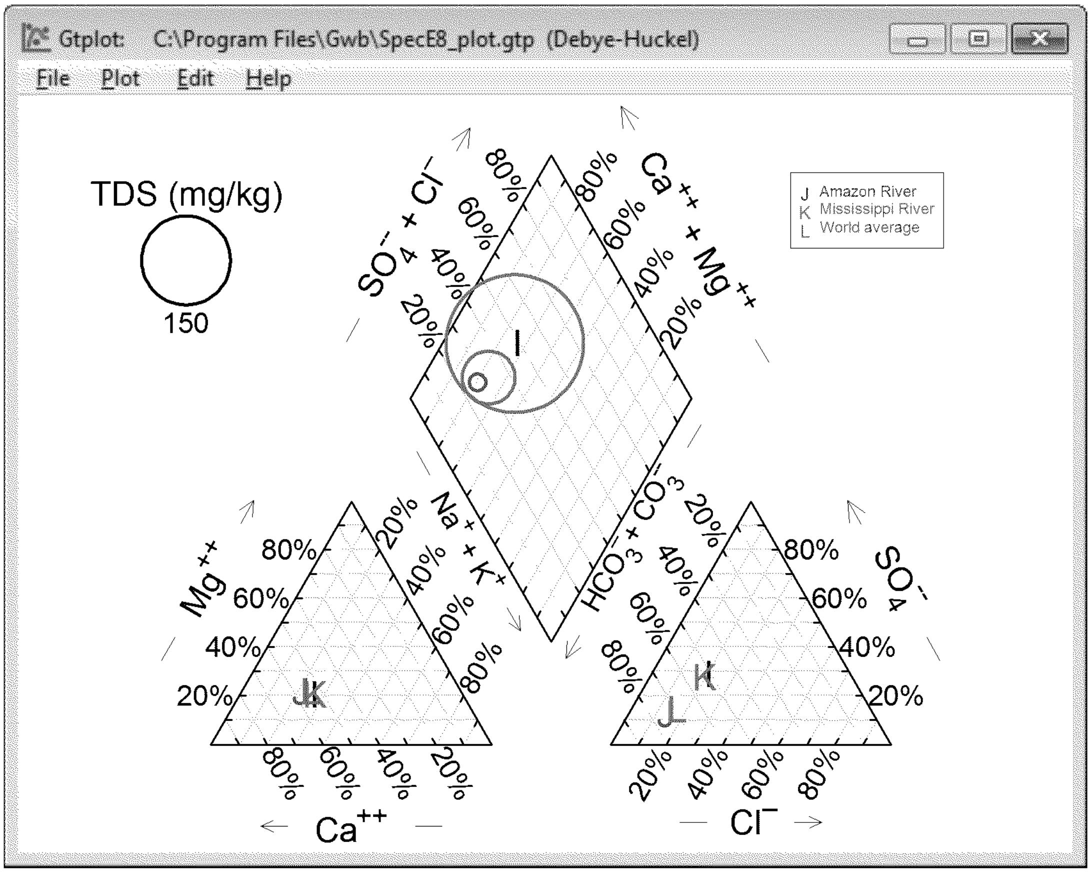


Figure 1.2 Program Gtplot's shell, showing graphics area and menubar. You configure Gtplotusingthe mouseto selectoptionsfrom the menubar,or by left-clicking, right-clicking or double-clicking on aspects of the plot.

Program Gtplot contains a graphics area and a menubar, but there are no panes to select (Figure 1.2). You configure this program using the mouse (or keyboard shortcuts) to select options from the menubar, or by left-clicking, right-clicking, or double-clicking on aspects of the plot displayed.

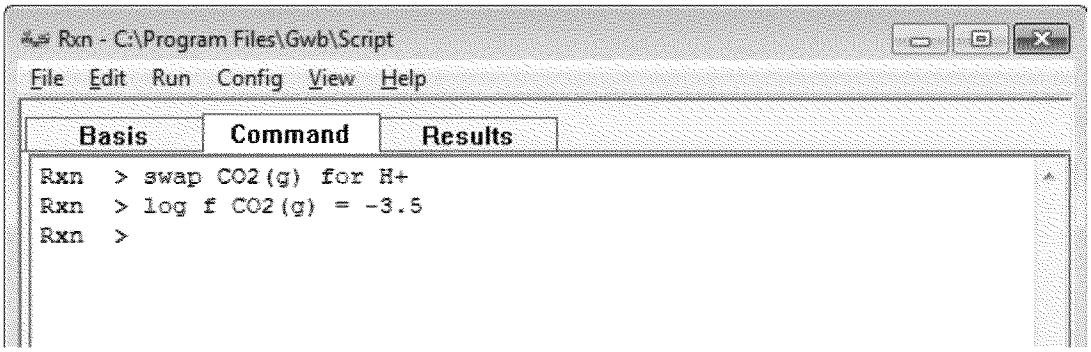


Figure 1.3 The Command pane for program Rxn. By selecting this pane, you can type Rxn commands at the command prompt. Alternatively, each command has a GUI equivalent, which you can exercise on the Basis pane, or by selecting options or dialog boxes from the menubar.

1.5 To GUI or not to GUI

Some people like to work interactively with a GUI (a GUI is a Graphic User Interface, or "goo-ey"), whereas others prefer to type commands from the keyboard. In the GWB programs Rxn, Act2, Tact, SpecE8, React, X1t, and X2t, you can work either way, or switch freely from one to the other.

To enter commands, select the Command pane and type your input at the prompt, as shown in Figure 1.3. Alternatively, each GWB command has a GUI counterpart, which you invoke on a different pane, or by selecting an option or dialog from the program's menubar.

You can quickly find the GUI equivalents to each command by exploring the program, or consulting the command reference sections of the GWB Reference Manual. Example calculations in this Guide are most commonly shown as sequences of commands, because the commands can be listed concisely. You can work the examples following either the command listings or their GUI equivalents.

1.6 Saving and reading input files

You can save the current settings in Rxn, Act2, Tact, SpecE8, and TEdit for later use. To do so, select File ! Save As... (Ctrl+S). Alternatively, typing the command

```
save My_file.ac2
```

within Act2, for example, writes the program's current configuration into a dataset "My_file.ac2".

Saved datasets contain input commands that can be read later by the program. Select an input dataset using the File ! Open ! Read script... dialog, or by typing

```
read My_file.ac2
```

Alternatively, simplyopen thefile.Alistofmostrecently opened filescanbeaccessed with File ! Recent Files. The number of files in the list can be set in File ! Preferences.... The following filename extensions are defined under Windows for the GWB programs:

.rxn Rxn	.sp8 SpecE8	.x1t X1t	.gss GSS
.ac2 Act2	.gtp Gtplot	.x2t X2t	.tdat thermo data
.tac Tact	.rea React	.xtp Xtplot	.sdat surface data

Double-clicking on "My_file.ac2", for example, launches Act2 and executes the commands in the file.

Whenyouexitprograms Rxn, Act2, Tact, SpecE8,and GSS,theyautomaticallysave their current configurations to files such as "rxn_resume.rxn" and "act2_resume.ac2" in your profile directory (found by typing %appdata% in the Windows Explorer Addressbar,e.g.,"c: \DocumentsandSettings \jones\ApplicationData \GWB").Upon re-entering the programs, you can restore the previous configuration by choosing File ! Resume, or typing

```
resume
```

from the command line. Set the File ! Resume On Startup option if each time you start one of the programs you would like to resume your previous session automatically.

Gtplot automatically saves the previous plot configuration in a dataset named "gtplot_conf.gtc" when you exit the program with the File ! Quit option (Ctrl+Q). When you restart in the same working directory, or when you open to ".gtc" file, the program configuration is restored. You can reset the configuration by choosing File ! Reset configuration (Ctrl+R) or use the File ! Save As... option (Ctrl+S) to save different configuration files in the same directory (see Using Gtplot).

1.7 Drag and drop feature

The drag and drop feature is a convenient way to transfer data withinor between GWB programs, or between GWBprograms and any other application that supports it.

Draganinput filefromyour Desktopor Windows Explorer intot heGWBdashboard or any GWB application, and the input will be automatically loaded. For example, you could drag a script file (.sp8) or thermo data file (.tdat) into SpecE8, or drag a configuration file (.gtc) into Gtplot.

Left-click, drag onto a GWB app, and release:

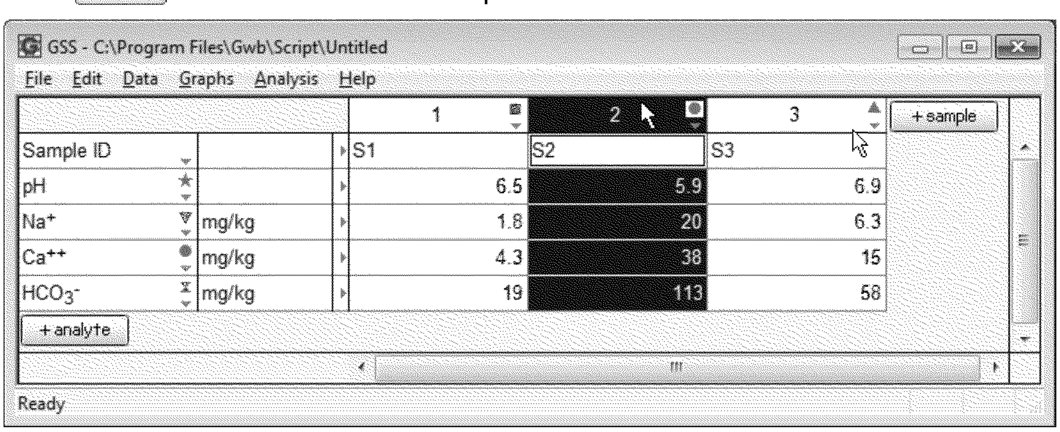
- Input scripts and files.
- Thermo and surface reaction datasets.
- Conductivity data and water standards.
- Plot configuration files.

Scatter data and reaction traces.

You can drag chemical data directly from your spreadsheet or table into any GWB program. Drag data to the Basis pane of SpecE8 or React to analyze an individual sample, to one of the panes in X1t or X2t to constrain the initial, inlet, or injection fluids, or into GSS to transfer your data.

In GSS, right-click on an individual cell or on the sample header (to select an entire sample) and drag. In Excel, Word, or PowerPoint, highlight the cell or column, left-click the frame surrounding it and drag. Release the mouse button over the selected input pane in the GWB program.

If dragging into GSS, bring the pointer to a sample header to fill that sample, or to the + sample button to add new samples.



Right-drag samples:

- from one GSS data sheet to another.
- from GSS into Basis, Initial, Inlet, Inject panes.
- from GSS into Excel.

Left-drag:

- samples from Excel into GSS.
- samples from Excel into Basis, Initial, Inlet, Inject panes.
- in GSS to rearrange samples or analytes.

Right-click and drag any pane title to transfer data within a GWB program, from one GWB program to another, or to another application. For example, in X1t or X2t, if you want to copy values from one input pane to another, right-click the pane title (such as Initial) and drag to any of the other fluid pane titles (Inlet or Inject).

In React, in order to "pick up" the results of a calculation and use these results as the starting point for a new calculation, right-click the Results pane title and drag onto the Basis pane.

Calculation output can be copied from the Results pane to any other application in the same way. Dragging the Results pane will copy and paste the last step components in the fluid.

Right-click on a dialog title bar and drag to copy the settings of the dialog box from one GWB application to another. For example, if in SpecE8 you have the Alter Log Ks dialog all set up and filled with the values you would like to use in React, right-click the Alter Log Ks dialog title bar and drag into React. The destination dialog box does not need to be open at the time.

Right-drag panes and dialogs to transfer:

- data from one instance of React, e.g., to another.
- data from one GWB program to another.
- in X1t and X2t, data among Initial, Inlet, Inject panes.
- in React, calculation results from the Results pane to the Basis pane.
- calculation results into GSS.
- Basis, Initial, Inlet, Inject pane values into GSS.
- data into Excel, Word, PowerPoint.

  text into WordPad to see what the drag/drop actual text is.

You can rearrange the order of the panes by left-dragging the pane titles. You may also detach each pane by left-clicking on the pane title and dragging it to the desktop. In this way you can arrange and size the panes individually to view and work with several panes at the same time. For example, you can type commands in the Command pane and immediately see the effect on the Basis, Results, and Plot panes. Re-attach panes with their close buttons. View ! Reset Windows resizes, re-attaches, and reorders all of the panes to the default configuration.

You can drag data tables, elements, any type of species, or virial coefficients from one thermo or surface dataset open in TEdit to another. Left-click an entry on the tree structure of the source dataset, drag to the tree structure or current entry of the target dataset, and release. If the source and target datasets are open in the same TEdit window, you can switch to the target dataset by hovering over its tab while dragging.

Left-drag panes:

- to rearrange the order of the panes
- to detach panes and arrange them on the desktop.
- re-attach panes with their close buttons or View ! Reset Windows (Alt+S).

The User's Guides provide many examples of how to configure the programs, how to use the various commands, and how to create input scripts. You can highlight any of these examples in the .pdf files, left-click within the selected text, drag with the left mouse, and drop onto a GWB program. The commands will be automatically executed in order. Open the Run ! History... dialog box to review them, or type "history" on the Command pane. You might also create an input script by dropping the selected text into an application such as WordPad and saving the file as a plain "Text Document" with the appropriate extension (.sp8, .rea, etc.).

*Note: If you are having trouble with Adobe Reader X drag and drop, go to Edit ! Preferences ! Categories ! General and uncheck “Enable Protected Mode at startup”.

Left-drag from the .pdf User's Guides:

- command examples to the GWB programs or other applications.

  script examples to the GWB programs or other applications.

Ifyouhaveaspreadsheet whichcontains theresultsofalarg e number ofanalyses, analternativetodraganddropistoprepareashortscriptth atperformstheoperations automatically, reading the analyses one at a time and adding the calculation results to the spreadsheet. For details of this process and a fully worked example, refer to the Multiple Analyses appendix of the GWB Reference Manual.

1.8 Helpful features

The command line interface for the Command pane in Rxn, Act2, Tact, SpecE8, React, X1t, and X2t includes a number of helpful features:

- Spelling completion. When you type commands in the Command pane, the programsautomaticallycompletethespellingofamineral, chemical,orcommand name (given enough characters to identify the name uniquely) — just touch the [tab] key. When the program cannot identify a unique name, it will cycle through the possible completions with subsequent [tab] key presses. You can also show all names beginning with a combination of characters by touching Ctrl+D.
- Commandhistory. Theprogramsmaintainalistofpreviouslyexecutedcommand s, which may be retrieved, modified, and re-executed. Type "history" or select Run ! History... to view the history list.
- Special characters. A group of control characters is provided on the Command pane for purposes such as spelling completion and input correction.
- Startup files. Users can establish files in their profile directories containing commands for Rxn, Act2, Tact, SpecE8, React, X1t, and X2t to execute at startup. These files should be named with the app name and _startup (e.g., act2_startup.ac2) and placed in your profile directory (found by typing %appdata% in the Windows Explorer Address bar, e.g., "c:\Documents and Settings\jones\Application Data\GWB").
- Calculator. The interface will automatically evaluate any numerical expression typed in the Command pane. This feature facilitates, for example, conversion of numbers to logarithms, or vice versa.

  Online documentation. The GWB User's Guides are available in pdf format online from any of the GWB programs. Select Help on the menubar to access them.

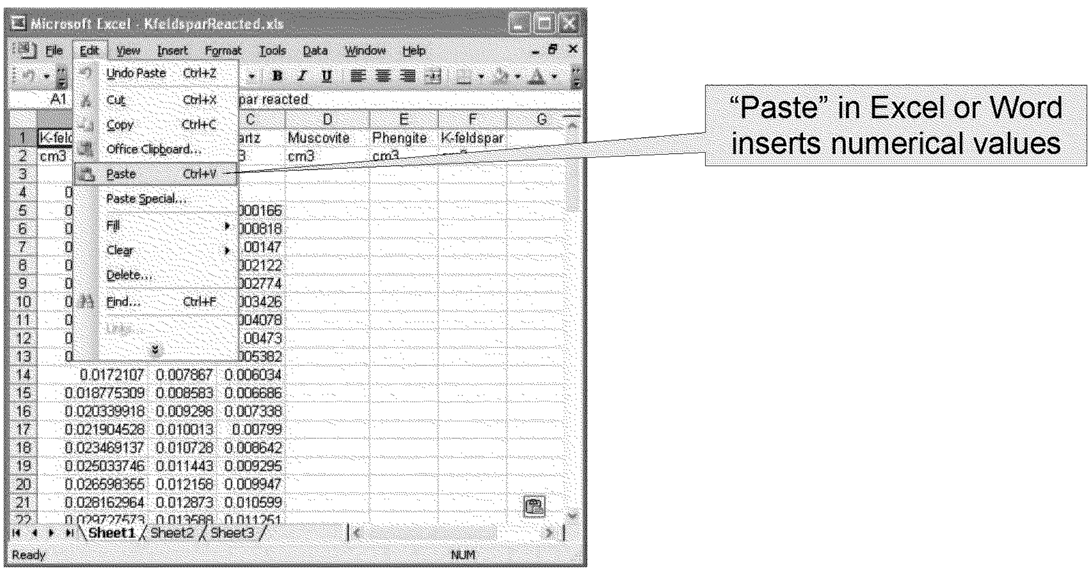
These features are described fully in the User Interface appendix to the GWB Reference Manual.

1.9 Exporting results

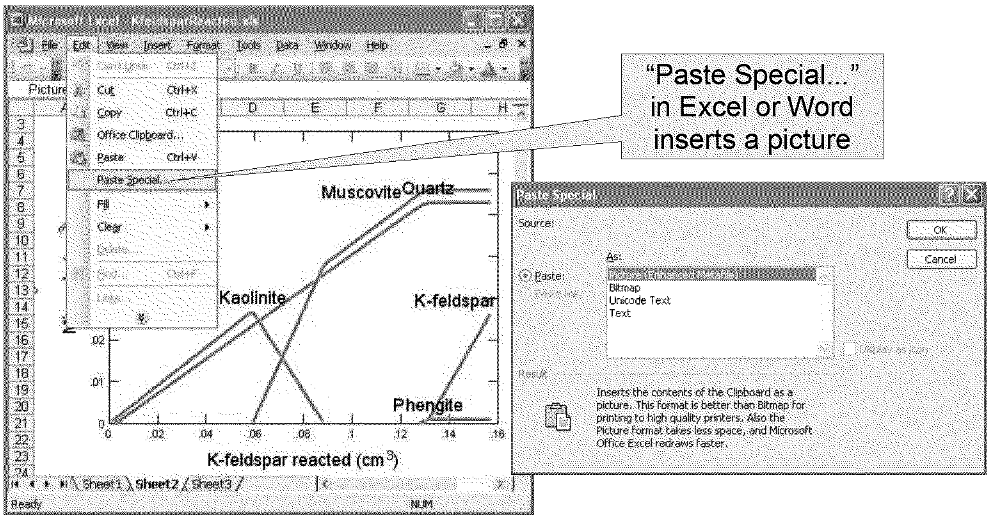
Programs Act2, Tact, Gtplot, and Xtplot make it convenient to use the plots you create in articles, reports, presentations, and databases. You can copy the current plot to the clipboard and then paste it into a variety of applications, in a format meaningful to the application.

Tocopyaplot,use Edit ! Copy or Ctrl+C. IfyoupastetheplotintoMSPowerPoint, it will appear as an EMF (an MS Enhanced Metafile) graphic object. Pasting into Adobe Illustrator places a native AI graphic.

If you paste a plot from Gtplot or Xtplot into MS Excel or a text editor such as Notepad or MS Word, the numerical values of the data points that make up the lines on the plot will appear in spreadsheet format.



In MS Word or MS Excel, use Paste Special... to paste the plot as a picture instead.



You can control the format in which the plot is copied to the clipboard by selecting Edit ! Copy As. You can choose to copy the plot as an AI object, an EMF object, a bitmap, or the data points in the plot, as tab delimited or space delimited text. Use the tab delimited option to paste the data into a spreadsheet program like MS Excel. For examining the data in a text file created with an editor like Notepad or MS Word, the space delimited option writes a nicely aligned table.

When importing AI graphics to Adobe Illustrator, the program may prompt you to update the legacy text before you can edit the file. In this case, choose "Update". You need to release the clipping mask before you attempt to edit individual elements of the plot. Use the "Ungroup" and "Group" functions when repositioning or modifying elements.

The programs can save plots to files in various formats by selecting File ! Save Image... from the menubar. The Graphics Output section of the GWB Reference Manual summarizes the options available for saving and using graphical output.

1.10 Automatic plot updates

The software is designed so that whenever program SpecE8, React, X1t, or X2t completes a simulation, any instances of Act2, Tact, Gtplot, or Xtplot that are displaying the results of that simulation will update their plots automatically.

1.11 Further reading

This guide is intended as an introduction to using the programs in The Geochemist's Workbench® Essentials package, and as a reference for the software package. For information about geochemical modeling in general, including a number of examples of how the software can be applied, please refer to the text “Geochemical and Biogechemical Reaction Modeling,” available from Cambridge University Press or book sellers such as Amazon. The chapter Further Reading in this guide gives literature references to this text and a number of other sources that provide starting points for further reading.

1.12 Users’ group

Gwb_users is an independent group of users who share comments and results and answer questions of general interest over the Internet. The group maintains an online forum that serves as a bulletin board for posting announcements, bug notices, and other current information about the software.

To subscribe to the forum (there is no charge), unsubscribe, or post a message, select GWB Users’ Group from the Windows Start menu (Start ! Programs ! Geochemist’s Workbench 9.0 ! GWB Users’ Group), or the Help pulldown in any of the GWB programs. Alternatively, you can visit the group’s home page at www.gwb.com.

Configuring the Programs

2.1 Configuring a calculation

Rxn, Act2, Tact, and SpecE8 all work in the same manner. Each program maintains a set of species, known as the basis, with which it writes reactions. Initially, the basis is the set of aqueous species that appears at the beginning of the thermodynamic database (see Table 2.1). This set is known as the "original basis."

You change the basis by "swapping" an entry into the basis in the place of an original basis species.

You can alter the basis to reflect the geochemical constraints that you wish to impose in your calculation by substituting ("swapping") another aqueous species, mineral, or gas for an entry in the original basis. To specify equilibrium with quartz, for example, you swap quartz for the basis species SiO_2(aq). Or, to set the CO_2 fugacity of your geochemical system, you swap CO_2(g) for either the HCO_3 or H^C basis entries. Examples in Chapters 4–7 illustrate the basis swapping technique.

To perform a calculation, you follow these steps:

1. Set the basis. First, add or swap the aqueous species, minerals, or gases you wish to use to constrain your calculation into the basis. The basis should contain any species at known activity, such as H^C if the pH is known, minerals co-existing with the system, or gases at known fugacity. If you are calculating a stability diagram, make sure that the basis also includes the species to appear on the diagram axes.
2. Constrain the basis. Next, specify the temperature for the calculation and assign a value ("constraint") for total concentration, activity, or fugacity for each entry in the basis.
3. Go. Select Run ! Go to initiate the calculation, which might be letting the program balance a reaction, calculate and display a diagram, or trace a reaction path.

Ag+	Silver	Mg++	Magnesium
Am+++	Americium	NO3-	Nitrogen
Au+	Gold	Ni++	Nickel
Ba++	Barium	O2(aq)	Oxygen
Ca++	Calcium	PuO2++	Plutonium
Cs+	Cesium	Rb+	Rubidium
Co++	Cobalt	SeO3-	Selenium
Cu+	Copper	Sr++	Strontium
F-	Fluorine	TcO4-	Technetium
HPO4-	Phosphorus	Sn++++	Tin
I-	Iodine	V+++	Vanadium
Fe++	Iron	Zn++	Zinc
K+	Potassium		

4. Revise. When the calculation is completed, you may adjust the basis by adding new components or varying your constraints; then, recalculate the model. You can continue to revise and recalculate until you decide to quit.

2.2 Setting and constraining the basis

You set the basis by adding the appropriate entries for the original basis list (Table 2.1) to the calculation. Then, if necessary, you swap another species, mineral, or gas for the original basis entry. If you prefer to type your input, you use the “add” and “swap” commands.

To configure the basis with the GUI, move to the Basis pane. You will see a list of current basis entries. Click the add button (Ctrl+N) to add an entry to the basis. A menu of available entries appears. Navigate the menu with the mouse, the up and down arrow keys, or by typing the entry's first letter (which is generally upper case). To swap, click on the entry's ⇄ button, and select an aqueous species, mineral, or gas to swap into the basis.

Once you have created a list of basis entries (e.g., as shown in Table 2.1), you can manipulate it in several ways. You constrain an entry by choosing a unit (e.g., the activity of a species or fugacity of a gas) and setting a value in the corresponding box.

You can change the order of the entries by simply dragging them. To delete a basis entry, or several, select the entire entry and touch the Delete key or the delete button. To configure another invocation of the program with these entries, right-click on the pane title, drag it, and release (see Drag and drop).

2.3 Thermodynamic datasets

The programs work from one of several versions of a thermodynamic database. Each database contains the properties of aqueous species, minerals, and gases, equilibrium constants for reactions to form these species, and data required to calculate activity coefficients. In most cases, the data span the temperature range 0°C–300°C, at one atm pressure below 100°C, and along the vapor pressure of water at higher temperature.

Youcanview,edit,andevencreateyourownthermodatasetsi nthe TEdit graphical editor, which is accessible from the Support pane of the GWB Dashboard (see Using TEdit). Since a thermo dataset is simply an ascii (character) file, you can alter it also using a text editor such as Notepad. The Thermo Datasets appendix to the GWB Reference Manual gives details of the database format.

The most commonly employed dataset is "thermo.tdat", which supports activity coefficients calculated according to an extended form of the Debye-Hückel equation (the "B-dot" equation; see Activity coefficients under Using SpecE8). The database was compiled by Thomas Wolery, Joan Delany, Ken Jackson, James Johnson, and other members of the geochemical modeling group at Lawrence Livermore National Laboratories (LLNL). The dataset is based in large part on the SUPCRT data compilation (see references inthe Further Reading appendix). Correspondence regarding the dataset may be addressed toJames Johnson, L-219, LLNL, Livermore, CA 94550.

From time to time, LLNL releases updated and expanded versions of its thermodynamic databases. A dataset "thermo.com.V8.R6+.tdat" is distributed with the GWB. This dataset is the LLNL "combined" dataset, version 8, release 6, in which the redox coupling among organic species has been modified somewhat. You may prefer to use this dataset if you are working extensively with systems containing organic species.

SpecE8, React, X1t, and X2t can also use virial methods (the "Pitzer equations") to model species activities in saline fluids. Such calculations require thermo datasets containing the virial coefficients. Dataset "thermo_hmw.tdat", included with the software release, includes coefficients for the Harvie-Møller-Weare activity model (see Activity coefficients under Using SpecE8). There is no provision in this dataset for calculations at temperatures other than 25°C.

Dataset "thermo_phrqpitz.tdat" is the database used by the USGS program PHRQPITZ. This database is a slightly expanded version of the Harvie-Møller-Weare activitymodelthatcontainsdataformorecomponentsthant heoriginal,aswellassome provision for temperature extrapolation. Before applying this dataset at temperatures other than 25°C, however, you should study the PHRQPITZ documentation (see Further Reading) carefully.

Three other datasets are provided with the GWB release. The datasets "thermo_minteq.tdat", "thermo_phreeqc.tdat", and "thermo_wateq4f.tdat" contain data from the MINTEQ, PHREEQC, and WATEQ4F software packages, which can be downloaded from the Visual Minteq home page (MINTEQ) and the U.S. Geological Survey (PHREEQC and WATEQ4F). When the GWB programs load these datasets, they use the same method as the original program (MINTEQ, and so on) to calculate activity coefficients.

By default, the programs at startup look for a dataset named "thermo.tdat", but you can specify an alternative default dataset in File ! Preferences. . . . If you set the defaultfiletomythermo.tdat, forexample,theprogramswil lreadafile"mythermo.tdat" as the default thermo dataset.

The programs at startup look for the thermodynamic dataset in your working directory and, failing to find it there, in the public "gtdata" directory (by default, "\Program Files\GWB\Gtdata"). You may set an alternative default directory in File ! Preferences. . . .

2.4 Redox couples

The thermodynamic dataset contains a number of redox coupling reactions that link species of differing oxidation states. There are redox couples between Fe^{CC} and Fe^{CCC}, HS and SO_4, CH_4(aq) and HCO_3, and so on. You can enable or disable coupling reactions interactively. In this way, you control the extent to which the programs honor redox equilibrium in their calculations.

Each of the redox coupling reactions is identified by a redox species, which is a basis species in an alternative oxidation state (Table 2.2). In the examples

4	3	2	1	0	C1	C2	C3	C4	C5	C6	C7	C8
							Am^{CCC}	Am^{CCCC}	AmO_2^{C}	AmO_2^{CC}		
					Au^{C}		Au^{CCC}					
			Cl								ClO_4	
						Cr^{CC}	Cr^{CCC}		CrO_4	CrO_4		
						Eu^{CC}	Eu^{CCC}					
				$H_2(aq)$	H^{C}							
						Mn^{CC}				MnO_4	MnO_4	
							Np^{CCC}	Np^{CCCC}	NpO_2^{C}	NpO_2^{CC}		
						Ru^{CC}	Ru^{CCC}	$Ru(OH)_2^{CC}$		RuO_4	RuO_4	RuO_4
		Se						SeO_3		SeO_4		
							Tc^{CCC}	TcO^{CC}	TcO_4	TcO_4	TcO_4	
							U^{CCC}	U^{CCCC}	UO_2^{C}	UO_2^{CC}		
							V^{CCC}	VO^{CC}	VO_4			

in the previous paragraph, Fe^{CCC}, HS and CH_4(aq) are the redox species; the corresponding basis species are Fe^{CC}, SO_4 , and HCO_3. The programs by default honor each redox couple and hence assume redox equilibrium. You can disable any number of the couples, however, by selecting Config ! Redox Couples. . . , or invoking the “decouple” command.

Once a redox couple has been disabled, the redox species in question becomes an entry in the basis list and can be constrained independently of the other basis entries. In an equilibrium calculation, for example, you need only constrain the basis entry Fe^{CC} and the oxidation state to consider ferrous and ferric iron species. By disabling the redox couple between Fe^{CCC} and Fe^{CC}, however, ferric and ferrous iron are treated separately. You would need to further constrain Fe^{CCC} to include ferric iron species in the calculation.

Redox reactions in a thermo dataset are set out in a flexible fashion, in terms of a redox pivot, which may be either O_2 or H_2. Where the pivot is O_2, redox reactions may be balanced in terms of the species O_2(aq), O_2(g), or as half-cells in terms of e . For the case of H_2, reactions are balanced using H_2(aq), H_2(g), or e .

2.5 Sorption onto mineral surfaces

Programs Rxn, SpecE8, React, X1t, and X2t can account for the sorption of aqueous species onto mineral surfaces by several methods, including the two-layer surface complexation model (including the constant capacitance and constant potential models), ion exchange, distribution coefficients (K_d's), and Langmuir isotherms.

In each case, you supply a dataset of surface reactions. You can load into the GWB modeling programs more than one surface dataset, and can mix datasets representing different methods in a single program run. Program TEdit provides a graphic interface for creating and modifying surface datasets.

2.5.1 Two-layer surface complexation model

Rxn, SpecE8, React, X1t, and X2t can account for surface complexation reactions by which species in solution sorb at 25'C onto mineral surfaces. The programs employ the modified two-layer model, as presented by Dzombak and Morel (see Further Reading). By this model, surface complexes form by reaction of aqueous species with sites on a mineral surface.

Dataset "FeOH.sdat" contains reactions for hydrous ferric hydroxide, which sorbs strongly and plays a significant role in many oxidizing environments. Alternative datasetscanbeprepared inaparallelformatforother sorbingminerals.Theprograms can consider several types of surfaces at a time. Each surface, furthermore, may occur on more than one mineral (e.g., a sorbing silica surface might be distributed across several zeolite minerals) and can contain a number of sorbing sites.

The "FeOH.sdat" dataset considers two types of sites, labeled >(s)FeOH and >(w)FeOH.Thesesitesrepresent, respectively,stronglyan dweaklysorbing positions on the surface. The dataset specifies that the sites occur on the surfaces of three minerals — hematite, $Fe(OH)_3$ precipitate, and goethite — and sets specific surface areas and sites densities for each.

The remainder of the dataset contains reactions describing the protonation, deprotonation, andcomplexationofsurfacesites.Thereac tions, eachwithaspecified log K, yield surface species such as >(w)$FeOH_2^C$, >(w)FeO , and >(w)$FeOCa^{CC}$.

There is provision in the dataset for specifying a temperature derivative of the log K values, but for the current software version these fields should be left with entries of zero.

A second dataset “FeOH+.sdat” supplied with the GWB is identical to dataset “FeOH.sdat”, except it contains reactions from the Dzombak and Morel compilation forwhichlog K values havebeen only estimated.Athirddataset “FeOH_minteq.sdat” contains the surface complexation data from Visual Minteq release 2.20, for hydrous ferric oxide.

2.5.2 Constant capacitance model

The constant capacitance is a special case of the two-layer surface complexation model, as already described. In the two-layer model, the program calculates surface potential (, in volts) from the electrical charge density (←, in C/m^2/ on the sorbing surface according to the well-known result of Debye and Hückel. The capacitance C of the surface is the ratio

$$C \; D \leftarrow = \qquad (2.1)$$

where C has units of F/m^2.

When treating systems of relatively high ionic strength or low surface charge, or both, the value of C may be taken as constant. This assumption simplifies the calculation since can be calculated directly from ←. You set a constant capacitance model in Rxn, SpecE8, React, X1t, or X2t by loading a surface complexation dataset and then setting a value for capacitance in F/m^2 with the “surface_capacitance” command

```
surface_capacitance = 2
```

If you have loaded more than one dataset of surface reactions, you identify the surface in question with its “type”, as shown in the dataset header. For example, for dataset “FeOH.sdat” you could enter

```
surface_capacitance HFO = 2
```

To revert to the default relationship between surface charge and potential, you enter the command

```
surface_capacitance = ?
```

In this case, the program reverts to the standard two-layer model.

You may alternatively set a constant value for surface capacitance in the header of a surface complexation dataset. In this case, the value specified is carried unless the user modifies it with the "surface_capacitance" command.

2.5.3 Constant potential model

The constant potential model is a second special case of the two-layer surface complexation model. In the constant potential model, a single value of the surface potential is assigned, regardless of surface charge. Most commonly, the potential is set to zero, which is equivalent to ignoring electrostatic effects on ion sorption.

You set a constant potential model in Rxn, SpecE8, React, X1t, or X2t using the "surface_potential" command

```
surface_potential = 0
surface_potential HFO = 0
surface_potential = ?
```

to set a value for electrical potential in mV. The command has the same format as the "surface_capacitance" command discussed above.

You can also specify a constant value for potential in the header of a surface complexation dataset. Note that for a sorbing surface you can set a constant capacitance or a constant potential model, but not both.

2.5.4 Ion exchange

The GWB programs can model ion exchange reactions on mineral surfaces in two ways. The first and simplest, although less general method is toswap an activityratio into the basis and prescribe its value. For example, you could enter the commands

```
swap Ca++/Na+^2 for Ca++
ratio Ca++/Na+^2 = 0.2
```

ThismethodworksineachoftheGWBmodeling programs (Rxn, Act2, Tact, SpecE8, React, X1t, and X2t).

Usingthissimplemethodisequivalent toassumingthatther eservoir ofexchanging ions on the exchanging surface is sufficiently large that its composition can be taken as invariant. A second, more general method for modeling ion exchange is available in Rxn, SpecE8, React, X1t, and X2t. This method accounts for the number of sites on the exchanging surface.

To invoke the second method, you prepare a small dataset of exchange reactions, usingfile"IonEx.sdat"asatemplate.(Thisfileisdistribut edwiththeGWBandinstalled with the thermo datasets, generally in directory "\Program Files\GWB\Gtdata".) You can prepare the dataset to honor either the Gaines-Thomas, Vanselow, or Gapon convention.

Each exchange reaction is of the form

$$>XWA^{C}\ C\ B^{C} \qquad >XWB^{C}\ C\ A^{C} \tag{2.2}$$

where A^{C} and B^{C} are ionic species and >X: represents the exchanging site. For the Gaines-Thomas and Vanselow conventions, the exchange reaction involving a divalent ion takes the form

$$>XW_{2}A^{CC}\ C\ 2\ B^{C} \qquad 2\ >XWB^{C}\ C\ A^{CC} \tag{2.3}$$

where A^{CC} is the doubly-charged ion. Such a reaction under the Gapon convention takes the form

$$>XWA^{CC}_{1/2}\ C\ B^{C} \qquad >XWB^{C}\ C\ 1/2\ A^{CC} \tag{2.4}$$

A selectivity coefficient serves as the equilibrium constant for the mass action equation corresponding to each exchange reaction.

Itisimportant tonotethattheGWBcarries massactionequat ions forionexchange reactions written in terms of the activities rather than molalities of the aqueous species. In taking selectivity coefficients from the literature, therefore, you should be careful to check units and convert from total molality to free activity, as necessary.

2.5.5 Distribution coefficients (K_d's)

You can account for ion sorption in Rxn, SpecE8, React, X1t, and X2t according to the distribution coefficient or (K_d/ approach. This approach does not carry a mass balance on the sorbing sites, so it is straightforward to implement and hence rather popular. The method's accuracy, however, can be poor, so the technique should be applied with caution.

According to the distribution coefficient approach, sorption reactions are written

$$>M^{CC} \qquad M^{CC} \tag{2.5}$$

where $>M^{CC}$ and M^{CC} represent an ion in sorbed and free form. In the GWB, the distribution coefficient K_d represents the ratio of the sorbed mass, in moles per gram of solid phase, to the activity $a_{M^{CC}}$ of the free ion.

Note that in taking K_d values from the literature, you may need to convert the ion's total molality to free activity. It is important to remember, furthermore, that unlike other sorption models, the distribution coefficient approach carries the sorbed concentration in moles per mass solid, rather than liquid phase.

To set up a calculation, you read one or more datasets containing distribution coefficients for sorption reactions using the “surface_data” command. You prepare the datasets using as a template file “Kd.sdat”, supplied with the GWB release.

2.5.6 Freundlich isotherms

Freundlich isotherms are similar to the Kd approach, differing in that the sorbed mass $SM_{>M^{++}}$ of an ion, in moles per gram of solid phase, is given from the ion’s free activity, the Freundlich coefficient K_f, and an exponent n_f, according to

$$SM_{>M^{++}} = K_f\, a_{M^{++}}^{n_f} \tag{2.6}$$

where $0 < n_f < 1$. For an exponent n_f of one, the method reduces to the K_d approach. To invoke Freundlich isotherms, you prepare a dataset of surface reactions, using file “Freundlich.sdat” as a template.

2.5.7 Langmuir isotherms

In Rxn, SpecE8, React, X1t, and X2t, you can also describe ion sorption in terms of Langmuir isotherms. In this method, ions are taken to sorb according to a reaction

$$>L{:}A^{+} \quad >L{:} + A^{+} \tag{2.7}$$

where $>L{:}A^{+}$ is the surface complex, $>L{:}$ is a sorbing site, and A^{+} is the sorbing ion.

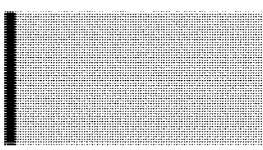
Each sorbing reaction has a corresponding equilibrium constant, commonly labeled K_{ads}. As with other reactions in the GWB, the equilibrium constants refer to mass action equations for dissociation reactions written in terms of species’ free activity, rather than total molality. You may, therefore, need to correct data for this unit change when extracting data from the literature.

The Langmuir method is in many ways similar to the two-layer surface complexation model. It does not, however, consider electrostatic forces. You set the number of sorbing sites explicitly, furthermore, instead of having the software calculate this number from the mass of a sorbing mineral.

To invoke a Langmuir model, you prepare a reaction dataset containing the sorbing reactions and their equilibrium constants. You prepare the dataset in the format of file “Langmuir.sdat”, which is distributed with the GWB as a template.

Using GSS

GSS –TheGeochemist'sSpreadsheet ™–isaprogramdevelopedtohold,manipulate, and graphtheresults ofwater chemistry analyses. GSS is afull-featured spreadsheet designed to work with the other software tools in The Geochemist's Workbench.



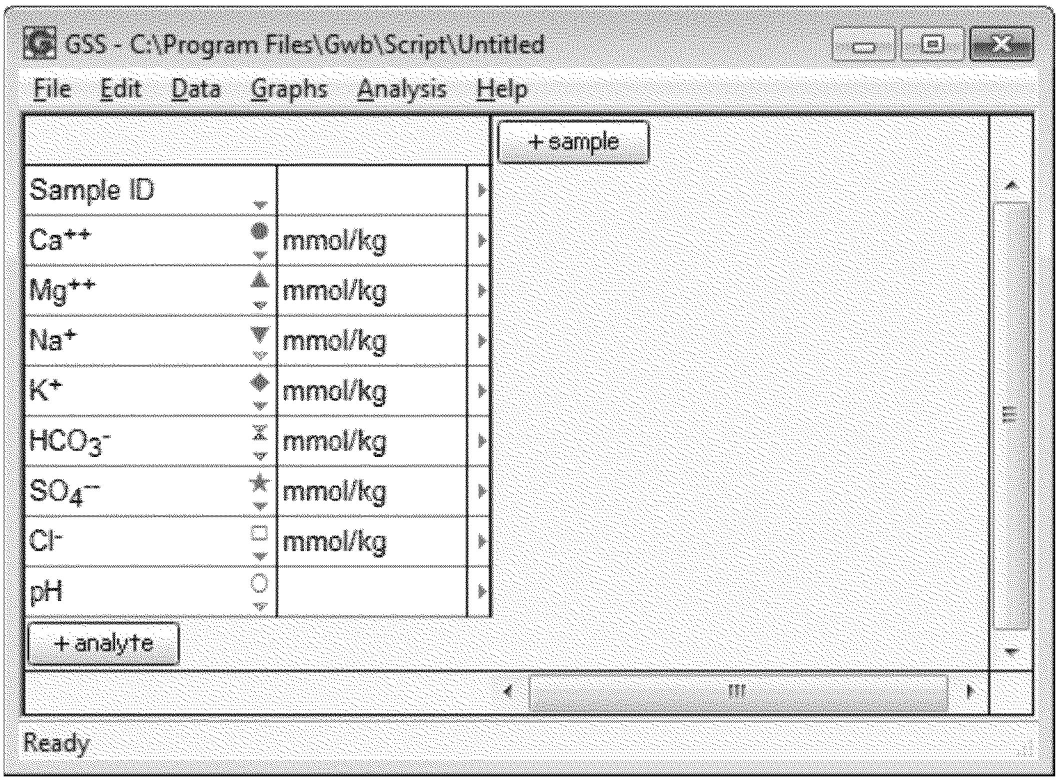
You enter or paste the analyses for all your samples, for each analyte you've measured, into a GSS data sheet. You can copy your data as a block and paste them in one step, so creating a data sheet need take only a moment. Once it's ready, you can do a number of things that would be difficult with an ordinary spreadsheet. You can, for example,

- Convert units with a click of your mouse.
- Use Gtplot to make cross plots and series or time series graphs.
- Create your favorite plots: triangular, Piper, Durov, Schoeller, Stiff, and so on.
- Overlay data on a redox-pH or activity diagram created with Act2 or Tact.
- Compare replicate analyses and check standards.
- Check results against regulatory limits or remedial objectives.
- Calculate speciation, mineral saturation, gas fugacity, and so on.
  Launch SpecE8 or React for any sample.

The next section describes how to set up your data sheet, and later sections tell you how to perform calculations and graph results. GSS is designed to get you up and running quickly, so there's no reason to hesitate.

3.1 Your first data sheet

To create a data sheet, start GSS or select File ! New if it is already running. You will see an empty data sheet



containing some common analytes.

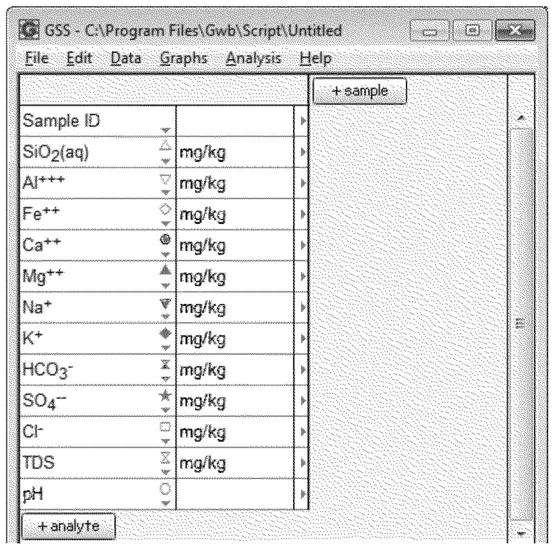
Begin by adding to the data sheet the analytes you need, and deleting those you don't.

Add analytes byclicking on + analyte and choosing fromvarious System parameters or any of the Basis species in the thermodynamic dataset. If you don't see what you need, choose User defined analytes and create your own. Or, you can add the analytes in one step using the Data ! Add Analytes... dialog. To delete an analyte, select it and touch the Delete key.

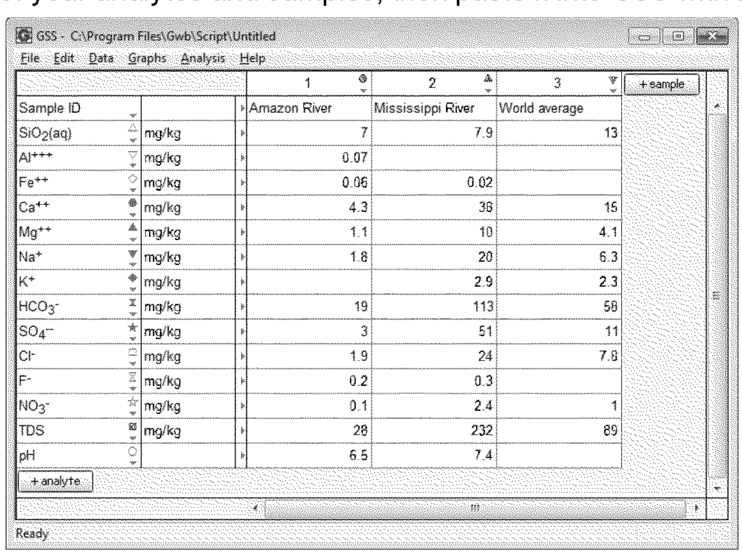
If the unit for an analyte doesn't match your data, right-click on it. To change units for more than one analyte, select a group of analytes by holding down the shift or control key, then right-click on the group. Using the "As" pulldown, you can set units as elemental equivalents: "mg/kg SO_4 as S" or "mg/l $As(OH)_4$ as As".

Now arrange the analytes to match your data. Simply drag an analyte, or a group of them, to the point in the list where you want it. To arrange the datasheet with the analytes in columns rather than rows, click Edit ! Transpose Data Sheet.

The data sheet might look like



You are ready to add your data. Click on + sample in your data sheet to create a column (or row) of empty data cells. You can enter values into the cells individually, but it's easier to copy from a source such as an Excel spreadsheet. Copy a block of values for all of your analytes and samples, then paste it into GSS with Edit ! Paste.



		1	2	3
Sample ID		Amazon River	Mississippi River	World average
$SiO_2(aq)$	mg/kg	7	7.9	13
Al^{+++}	mg/kg	0.07		
Fe^{++}	mg/kg	0.06	0.02	
Ca^{++}	mg/kg	4.3	38	15
Mg^{++}	mg/kg	1.1	10	4.1
Na^{+}	mg/kg	1.8	20	6.3
K^{+}	mg/kg		2.9	2.3
HCO_3^{-}	mg/kg	19	113	58
SO_4^{--}	mg/kg	3	51	11
Cl^{-}	mg/kg	1.9	24	7.8
F^{-}	mg/kg	0.2	0.3	
NO_3^{-}	mg/kg	0.1	2.4	1
TDS	mg/kg	28	232	89
pH		6.5	7.4	

You are ready to work with your data.

3.2 Working with a data sheet

Once you have set up a data sheet containing your data, you can work with it in various ways, as described in this and later sections of this chapter. Example datasets are installed with the software, under "\Program Files\GWB\Script". You can open one of these in GSS (File ! Open ! GSS Spreadsheet. . .) to experiment with the program.

3.2.1 Changing the view

You can change how the data is displayed on the current data sheet with the Edit ! Appearance. . . dialog, and the default appearance for data sheets under File ! Preferences. . . . There, you can set the font, point size, and number of significant digits shown in the data cells.

Zoom in and out with Edit ! Zoom In (Ctrl++) and Zoom Out (Ctrl+); Zoom 100% (Ctrl+Shift+Z) returns to the font size set in File ! Preferences. . . .

To change the width of the data cells, drag the dividing line between columns left or right. Dragging changes the width of all the data columns at once.

If you have too much data to view, you can temporarily hide analytes or samples. Select the rows or columns you wish to hide and under Data choose Hide Analytes or Hide Samples; restore the display with Show All Analytes or Show All Samples.

3.2.2 Data cells

Each cell in a data sheet contains a numerical value, such as the concentration of a species, a character string, or a date or time. If you have no data for a cell, set a character string such as "n/d", or just leave the cell empty.

Where an analysis falls below detection limit, enter a field such as "<0.01". GSS carries this value as it changes units, and will display it with a special "less than" symbol on plots.

You can enter dates in various formats: "Sep 21, 2009", "9/21/09", "September 23", and so on. GSS displays the field in the local format set for your computer. Enter time as a field such as "2:20 PM", "14:20", or "2:20:30 PM".

3.2.3 Changing units

To change units on the data sheet, select one or more analytes and right-click on the unit field, or choose Data ! Units. Either way, from the As option you can set concentrations in elemental equivalents, such as "mg/kg SO_4 as S". When you change units, you choose to convert the values in the corresponding data cells to the new unit, or leave the numbers unchanged.

Some unit conversions require knowledge of the fluid's dissolved solids content (the TDS) or density, or both. If you enter values for these analytes, GSS uses the entries directly. Otherwise, the program estimates values for each sample from the information provided. It is best in that case to enter the complete analysis for a sample before converting units, so GSS can estimate density and TDS as accurately as possible.

The program calculates TDSfor each sample by adding themass es of thesolutes, and figures density as that of an NaCl solution of the same TDS at the specified temperature, or 25°C if none is set. Converting from concentration units (mg/kg, mmolar, ...)toabsolute mass(grams,mmoles, ...)requires anentryforsolution mass. If a solution mass is not entered, the program calculates it from the concentrations given for the various solutes, assuming a solvent mass of 1 kg.

3.2.4 Error bars

Set an error bar for the entry in a data cell as a triplet of values separated by vertical bars. An entry 0.5|2.0|3.5, for example, appears in GSS plots as a data point at 2.0 overlying an error bar extending from 0.5 to 3.5. Entry 0.5| |3.5 appears as an error bar alone.

3.2.5 Calculating analytes

You can add a number of calculated values to your data sheet, including

- System parameters, such as TDS, electrical conductivity, and hardness.
- Components in fluid
- Free concentrations, activities, and activity coefficients of aqueous species.
- Saturation indices of minerals, such as calcite.

  Fugacities of gases, such as CO_2.

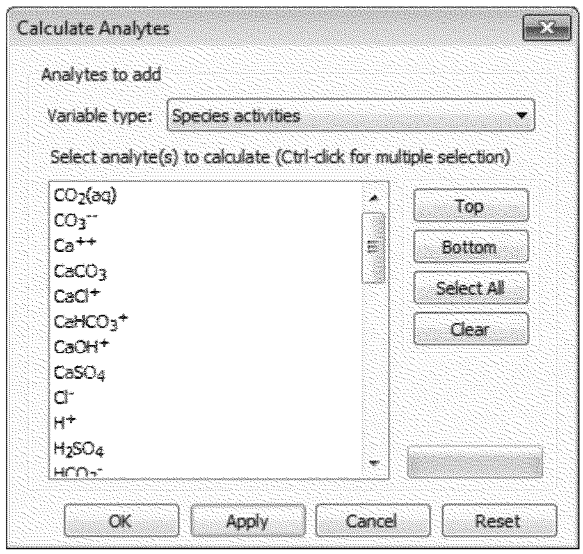
GSS doesn't do the calculation itself; instead, it sends data from the data sheet to program SpecE8, which does the calculations and returns the results to GSS. The SpecE8 program is described in the Using SpecE8 chapter of this guide.

Keep in mind that the order of the analytes in the data sheet is important. In its calculations, SpecE8 will use the first constraint it finds for a particular basis component. For example, if both Eh and O2(aq) are present, SpecE8 will use whichever is first in the data sheet. You can easily change the order of the analytes by dragging, or hide analytes you don't want used in the calculations.

If the data sheet has hidden analytes, "less than" (<0.001) values, or zero values, youmay choosetoomitthem when generating input for SpecE8 inthe Constraints...

dialog. Youcanaddadditional commands tothe SpecE8 input thereorinthe Analysis ! Launch. . . dialog. Header lines will be inserted near the beginning, just after the thermo data is read. Trailer lines will be added to the end of the input.

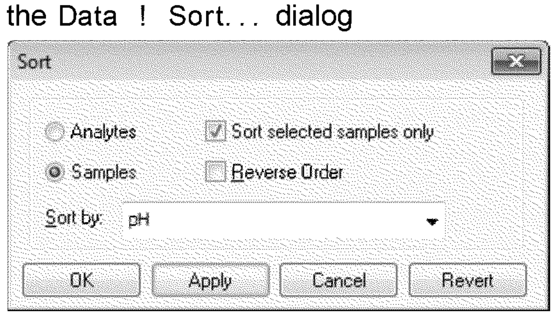
To add calculated analytes to your data sheet, click on + analyte ! Calculate. . . or Data ! Calculate. . . .



Choose from among the variable types listed one or more analytes, then click OK or Apply. The calculated data will appear as a new row (or column) of cells in your data sheet.

3.2.6 Sorting

You can sort the analytes or samples in the data sheet numerically, or alphabetically for text entries, with the Data ! Sort. . . dialog



You might sort analytes so the components with the highest concentrations appear at the top of the sheet, and the lowest at the bottom. Or you could sort samples so they are ordered with the most acidic pH values to the left and most alkaline to the right.

Classes of analytes are grouped together in the sorted results. Basis species, then, are grouped, not interspersed with system parameters or other analytes. Sort a subset of the data, instead of the entire data sheet, by selecting the data and checking the “Sort selected analytes/samples only” box. You can sequentially undo your sorts with the Revert button.

3.2.7 Notes

You can save information – the site’s location, who conducted the sampling, what laboratory analyzed the samples, and so on – along with your data sheet. To do so, select Data ! Notes.... Information you type into the text box is saved with your GSS document.

3.2.8 Undo and redo

You can reverse one or more recently performed actions in GSS by choosing Edit ! Undo, or touching Ctrl+z. You set the number of levels of undo allowed on the File ! Preferences... dialog. To cancel the effects of an undo, select Edit ! Redo or touch Ctrl+y.

3.2.9 Saving and exporting data

When you choose File ! Save, GSS saves your data sheet as a “.gss” file. Files of this type are in a special format that contains not only the entries in the data cells, but the settings for the program options, the display, the name of the thermo dataset, and so on.

You can export the entries in a GSS data sheet to other programs in several ways. The easiest way is to use GWB’s drag and drop feature (see Drag and drop). In GSS, select a Sample ID with the right mouse button, drag to the other program and release. Alternatively, you can select the data cells of interest, copy them to the clipboard (Edit ! Copy), and paste them in an application such as MS Excel, Notepad, or MS Word.

You can also save the data sheet as a tab-delimited or comma-delimited file (“.txt” or “.csv”) that other applications can read. Select File ! Save As... and choose the file type and file name. You can specify on this dialog the data orientation and whether to export hidden analytes or samples.

3.2.10 Resuming your session

You can continue working on the data sheet from the last time you had GSS open by choosing File ! Resume. To have GSS do this automatically each time you open the program, set File ! Resume On Startup.

3.3 Analytes

Analytes are the measurements or sample properties that GSS can store, use, and display. Analytes in GSS fall into four categories:

- System parameters
- Basis species
- Calculated values
- User defined analytes

3.3.1 System parameters

A number of commonly used analytes are pre-defined within GSS. The "system parameters" include temperature, pH, Eh, TDS, and so on.

3.3.2 Basis species

Each of the primary basis species and redox species in the thermodynamic dataset loaded with your session is available as an analyte. The primary basis species might include components such as Na^{C}, Ca^{CC}, Cl , SO_4 , and Fe^{CC}, whereas Fe^{CCC}, HS , and so on might appear in the thermo dataset as redox species.

A number of thermo datasets are installed with the GWB software, and others are available on the web. When you create a new data sheet, GSS opens the thermo dataset listed in File ! Preferences..., looking for it in the directory shown. You can edit the entries in the thermo data or create your own dataset, as described in the Thermo Datasets appendix to the GWB Reference Manual.

To change datasets, use File ! Open ! Thermo Data..., or File ! Recent Files. File ! File Properties ! Thermo data shows information about the thermo dataset currently in use.

3.3.3 Calculated values

As described in the previous section, GSS can use SpecE8 to calculate

- Various system parameters, such as TDS, electrical conductivity, and hardness.
- Components in fluid.
- Species' concentrations, activities, and activity coefficients.
- Mineral saturation indices.

Gas fugacities.

as described in the Using SpecE8 chapter of this guide. Select + analyte ! Calculate... or Data ! Calculate... to add calculated analytes to the data sheet.

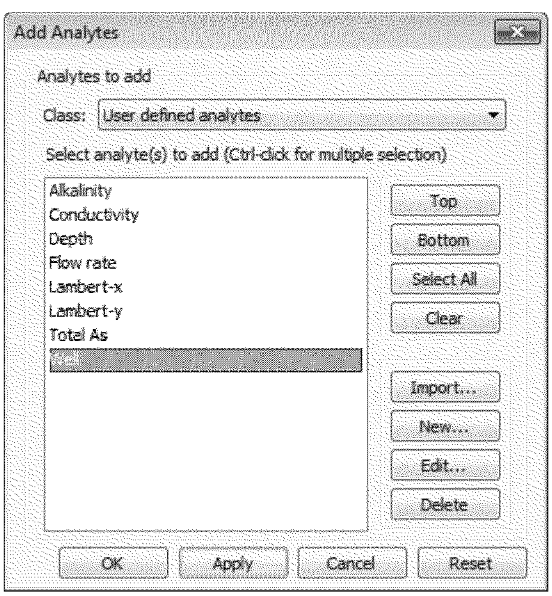
You can control the details of how SpecE8 figures calculated values by going to the Data ! Constraints... dialog. Here, you tell SpecE8 what to do if it encounters zero or "less than" values. You can also set commands (see SpecE8 Commands in the GWB Reference Manual) for SpecE8 to execute either before or after defining the chemical system, as it runs for each sample. You might, for example, enter a command such as

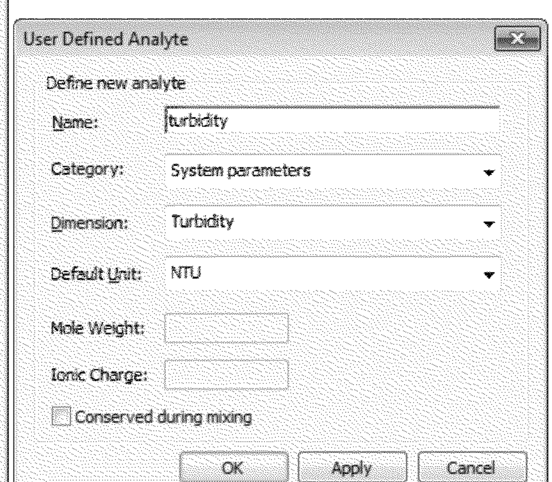
```
balance on SO4--
```

to cause the program to force an ionic charge balance.

3.3.4 User defined analytes

If you can't find the analyte you need, you can quickly define your own. You might, for example, set latitude or longitude as a text field, specify a numerical value for turbidity, and so on. To go directly to the User Defined Analyte dialog click + analyte ! User defined analytes ! New.... Alternatively, click + analyte ! User defined analytes ! Edit..., or Data ! Add Analytes.... This brings up the Add Analytes dialog where, with the "User defined analytes" class selected, you can create a new analyte by clicking New..., or alter an existing one with Edit.... To bring in an analyte from another .gss file, use the Import... button.





GSS keeps a list of your user-defined analytes – those you define and any encountered in data sheets you open – in your computer's registry, so they are available from one run to the next. To remove an analyte from the registry, select it on the Add Analytes dialog, then hit Delete and Apply.

3.3.5 Analyte properties

You can see the properties of each analyte in the data sheet by choosing Data ! Analyte Properties and selecting a class. The "Description" and "Source" fields can be set directly from the properties sheet; other fields are set in the thermo data, or from the User Defined Analytes dialog. To return to the data sheet, use the button on the right.

3.4 Regulations, replicates, standards, and mixing

GSS can flag analyses violating regulatory limits or remedial objectives, compare replicate analyses, check analytical standards, and mix water samples, as described in this section.

3.4.1 Flagging regulatory violations

GSS can flag in your data sheet entries that fall outside the regulatory limits or remedial objectives for an analyte. To flag violations, select the Analysis ! Check Regulatory Limits option. Entries below an analyte's minimum level or above its maximum appear on your data sheet enboldened in red.

GSS reads the regulatory limits from a text file that looks like

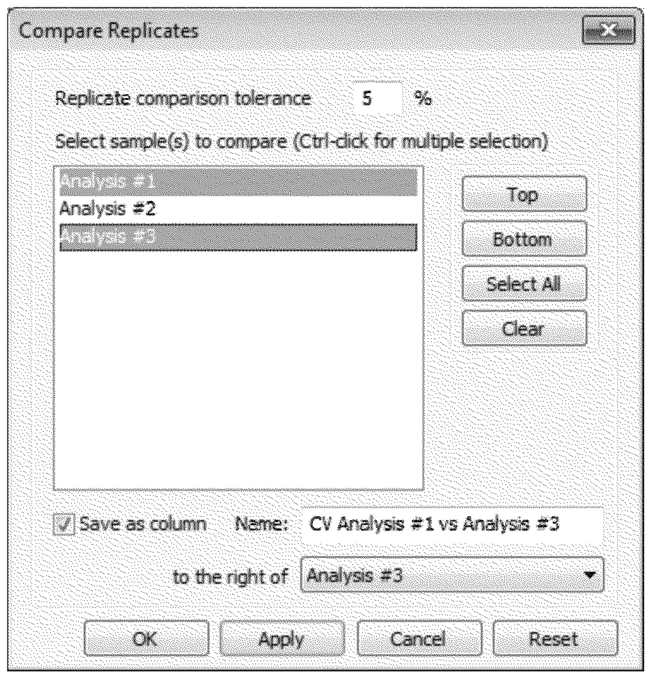
```
# Analyte     Min    Max    Unit              Notes
# ---------------------------------------------------------------------

Al+++         --     0.05   "mg/kg as Al"     NSDWR
AsO4---       --     0.01   "mg/kg as As"     MCL
AsH3(aq)      --     0.01   "mg/kg as As"     MCL
pH            6.5    8.5    pH                NSDWR
...
```

Youspecifythefiletoreadonthe File ! Preferences... dialog.Bydefault,theprogram reads a dataset "WaterQualityRegs.dat" installed with the software in "\Program Files\GWB". You can use this file, based loosely on the US EPA's drinking water standards, but most commonly you prepare a dataset to meet your own needs.

3.4.2 Replicate analyses

GSS can compare replicate analyses, analyses made of splits of the same sample, to verify the results agree to within an error tolerance. Select two or more samples on your data sheet, then choose Analysis ! Compare Replicates. . . . The dialog that appears



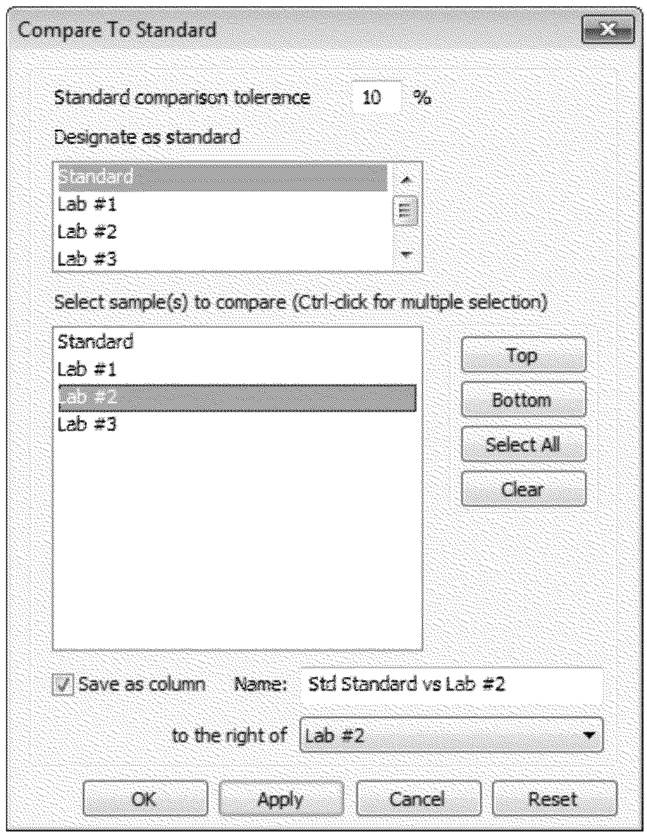
shows the error tolerance and the samples to be compared.

When you click OK or Apply, a column appears to the right (or bottom) of the data sheet showing the coefficient of variance among the samples for each analyte, along with a ✔ or ✗, depending on whether or not the variance is within the tolerance indicated. Small coefficients of variance indicate good agreement among the replicates.

To incorporate the variances into the data sheet, use the “Save as column” option. You can change the error tolerance, which defaults to ˙ 5%, by right-clicking on one of the errors. Close the replicate display by clicking on ⊠.

3.4.3 Checking standards

GSS can check analyses of standards, samples of well-known composition, for accuracy. Enter the standard's known composition in a data sheet, along with its analysis or analyses. Select the standard and at least one analysis, then choose Analysis ! Compare to Standard..., which opens a dialog



showing the error tolerance to be allowed, the standard itself, and the analyses to compare to the standard.

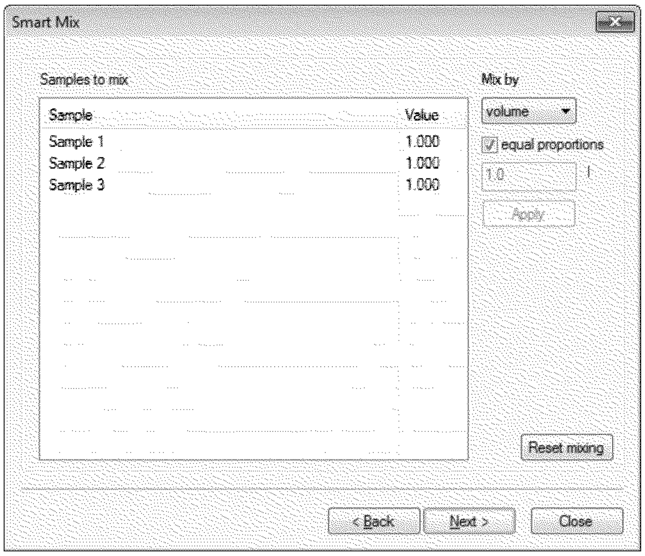
When you click OK or Apply, a column appears to the right (or bottom) of the data sheet showing the average deviation, along with a ✔ or ✖, depending on whether or not the deviation is within the tolerance indicated.

To incorporate the deviation results into the data sheet, use the "Save as column" option. You can change the error tolerance by right-clicking on one of the errors. Close the error display by clicking on ☒.

3.4.4 Mixing samples

GSS can show the results of mixing two or more water samples in any proportion using the values of the total components calculated using SpecE8. Choose Analysis ! Mix Samples... to open the Smart Mix wizard, then select the samples to mix and click Next >. A dialog box with settings for the mixing calculations will pop up. These are the same settings you specify in the Data ! Constraints dialog. Click OK to move on to the next step.

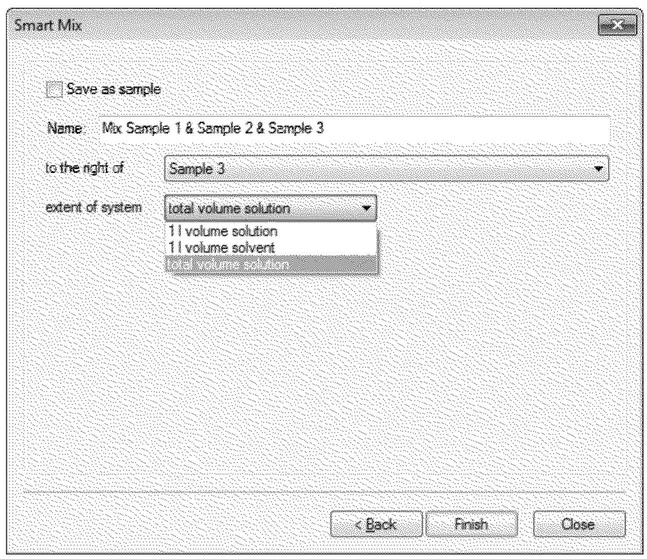
The wizard will list the Sample ID and the extent of the samples you've chosen to mix. GSS will mix samples volumetrically by default, but you can choose instead to mix samples gravimetrically by selecting “mass” from the “Mix by” pulldown. When the “equal proportions” option is checked, each sample will be assigned a value of 1 liter (or 1 kilogram of solution, if mixing by mass). By unchecking this option you can set values for samples individually. If you are mixing by mass and your spreadsheet includes values for the System parameter “Mass solution”, GSS will use those values. Otherwise, select a sample, set a value in the box and click the Apply button, then repeat for the remaining samples. The Reset mixing button returns all settings to their defaults. Click Next > to move on to the next step.



GSS will test each sample for convergence and report success or failure before beginning the mixing calculations. You can click More info... to see the SpecE8 input and calculation results for each sample. If a sample fails to converge, it will not be included in the mixing calculation. You can click Close to check the values in the spreadsheet before restarting the Smart Mix wizard, or click Next > to move on to the next step.

You can choose how GSS reports the extent of the mixed sample. If samples were mixed volumetrically, you can report the mixture's total solution volume or scale the results to 1 liter of solution or solvent water. If samples were mixed by mass, you can report the total mass of the mixed fluid, or scale the sample to 1 kilogram of solution or solvent water.

The composition of the mixture will appear to the right (or bottom) of the data sheet, showing the results for each analyte in thespreadsheet. Unlike GWBreleases 9.0 and earlier, GWB10 will automatically calculate the values of certain parameters that are not conserved during mixing, such as pH. Close the mixture display by clicking on .



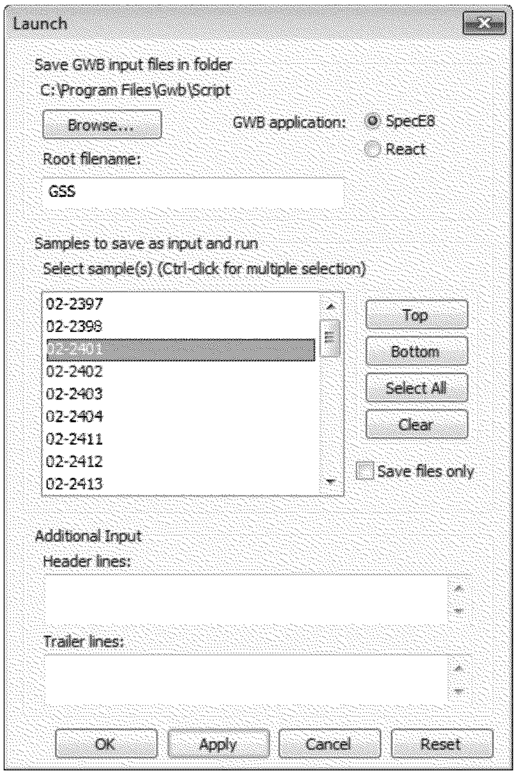
To work with the mixture as if it were a sample, select the "Save as sample" option. The result of the mixing calculation is placed in the data sheet as a new sample to the right of the selected column (or below the selected row).

3.5 Launching SpecE8 and React

You can use the chemical analyses in a GSS data sheet to set up and run SpecE8 or React calculations. These programs are described in the Using SpecE8 chapter in this guide and the Using React chapter in the Reaction Modeling Guide.

Selectoneormoresamplesonthedatasheet,thenchoose Analysis ! Launch.... If a sample has "less than" (<0.001) values, zero values, or hidden analytes, you may choose to omit them when generating the input.

You can add additional commands to the SpecE8 or React input script created by GSS. Header lines will be inserted near the beginning, just after the thermo data is read. Trailer lines will be added at the end of the script.



When you hit Apply or OK, GSS writes into the directory specified an input file for each sample you have selected. The input files are named (Root filename) + (Sample ID) + ".sp8" or ".rea".

Unless you have selected "Save files only", an instance of SpecE8 or React will be launched configured with the values in the first sample. If you have selected more than one sample, the program will do a batch run, writing the results to an output and plot file for each sample.

3.6 Graphing data

GSS can call on program Gtplot to diagram the data in your data sheet in a variety of ways. The Using Gtplot chapter in this guide describes in detail the Gtplot program and the types of plots it creates.

When making a diagram, it is best to begin with the Graph ! Selected Samples Only option not selected. Later you can plot only certain samples in the data sheet by turning the option on and choosing Graphs ! Update Graph(s).

3.6.1 Series and time series plots

To graph the entries in your data sheet as a series, sample by sample, select the analyte or analytes to plot and click on Graphs ! Series Plot. In the Gtplot window that opens, the samples are arrayed along the x axis in the order they appear in your data sheet. To change which analytes are shown, or the axis units or data range, double-click on the y axis label.

To associate markers or their colors or sizes with samples in the data sheet, rather than analytes, go to Edit ! GSS Data.... To control whether the markers are connected by line segments, right-click on a marker and select or de-select "Connect Scatter Points".

To change the marker representing an analyte or sample, click in GSS on the marker next to the analyte or sample name. Choose a symbol and its color and size, then click on Graphs ! Update Graph(s).

To create a time series plot, make sure either "Date", "Time" or "Time elapsed" appears as an analyte in the data sheet, then choose Graphs ! Time Series Plot and proceed as above.

3.6.2 Cross plots

To plot one analyte, or several, against another, select the analytes to appear in the diagram, then choose Graphs ! XY Plot. To change which analytes appear on the x or y axis, or the units or data range for either, double-click in Gtplot on the axis label. Control the markers and which samples appear in the plot as you would with a series plot.

3.6.3 Ternary, Piper, and Durov diagrams

To create a ternary (triangular) diagram, select in the data sheet three analytes to appear on the diagram axes, then choose Graphs ! Ternary Diagram. Change the analytes appearing on the diagram axes or the axis units by double-clicking on the axis label.

To plot a Piper or Durov diagram, select Graphs ! Piper Diagram or Durov Diagram. In any case, control the markers and which samples appear in the plot as you would with a series plot.

In order to see TDS represented as circles on Piper, ternary, and Durov diagrams, add TDS as an analyte in the data sheet and enter a value for each sample. As described in the Calculating analytes section of this chapter, you may select + analyte ! Calculate... or Data ! Calculate... to add calculated TDS to the data sheet.

3.6.4 Other diagrams

Create a Schoeller, Stiff, or radial diagram, or a bar or pie chart by selecting the sample you wish to represent and clicking on Graphs ! Schoeller Diagram, Stiff Diagram, Radial Plot, Bar Chart, or Pie Chart. Choose to plot another sample by opening the appropriate dialog (Schoeller Diagram. . . , and so on) in Gtplot under the Plot pulldown.

3.6.5 Scatter data

You can overlay the data entries in a GSS data sheet on any plot produced by the GWB applications, including activity diagrams made by Act2 and Tact, and plots of the results of reaction and reactive transport models from Gtplot and Xtplot.

To plot "scatter data," first save your data sheet as a .gss file. In Act2, Tact, Gtplot, or Xtplot,read the .gss file by selecting File ! Open ! Scatter Data. . . . Data points representing each sample will appear on the plot, if the .gss file contains analytes corresponding to the plot axes.

For details on plotting scatter data from .gss files, see the Using Act2, Using Tact, and Using Gtplot chapters in this guide, the Using Gtplot chapter in the GWB Reaction Modeling Guide, and the Using Xtplot chapter in the GWB Reactive Transport Modeling Guide.

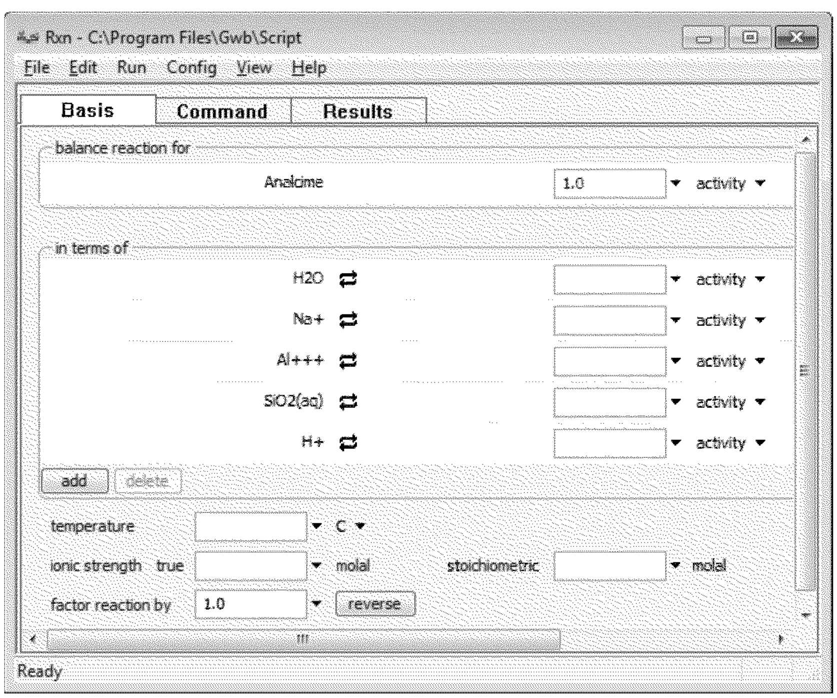
Ctrl+A	Select all cells in the data sheet
Ctrl+D	Select all data cells in the data sheet
F1	GWB Reference Manual
Shift+F3	Find previous instance
Ctrl+N	Create new data sheet
Ctrl+O	Open an existing .gss file
Ctrl+Q	Quit the program
Ctrl+S	Save the current spreadsheet to a file
Ctrl+U	Update graphs in Gtplot
Ctrl+W	Open a new water quality regulatory standards file
Ctrl+Y	Redo
Ctrl++	Zoom in
Ctrl+-	Zoom out
Ctrl+Shift+Z	Zoom 100% - to font size in Preferences...

Using Rxn

Start Rxn from the GWB dashboard, or by opening a ".rxn" file.

Rxn is a program that, among other things, automatically balances chemical reactions among minerals, dissolved species, and gases. The program is easy to use, and quite useful. To show the balanced reaction by which analcime dissolves to form aqueous species, for example, start the program and move to the Basis pane. Clicking on the entry (initially, it is "???") under "Balance reaction for", select "Analcime" from the list of "Minerals".

The Rxn window should look like this:



To see the balanced reaction, select Run ! Go, or press the Run button on the Results pane.

Alternatively, you can configure and run the program by selecting the Command pane and typing

```
react Analcime
go
```

In either case, the program gives the result

```
Analcime + 4 H+ = 3 H2O + Na+ + Al+++ + 2 SiO2(aq)
```

The species H^C, Na^C, etc., are members of the original basis set carried in the thermodynamic database (see Table 2.1).

You can change the basis to generate reactions in alternative forms. To see the reaction balanced in terms of quartz and albite in place of SiO_2(aq) and Al^{CCC}, use the ⇄ button to swap "Quartz" for "SiO2(aq)", and "Albite" for "Al+++". Or, continuing on the Command pane, type

```
(cont'd)
swap Quartz for SiO2(aq)
swap Albite for Al+++
go
```

(do not enter lines shown in italics). In this case, the program gives the result

```
Analcime + Quartz = H2O + Albite
```

Rxn will calculate a reaction's equilibrium constant at a temperature of interest whenever the temperature is given. To find the equilibrium constant for the above reaction at 250°C, set temperature on the Basis pane, or type

```
(cont'd)
T = 250
go
```

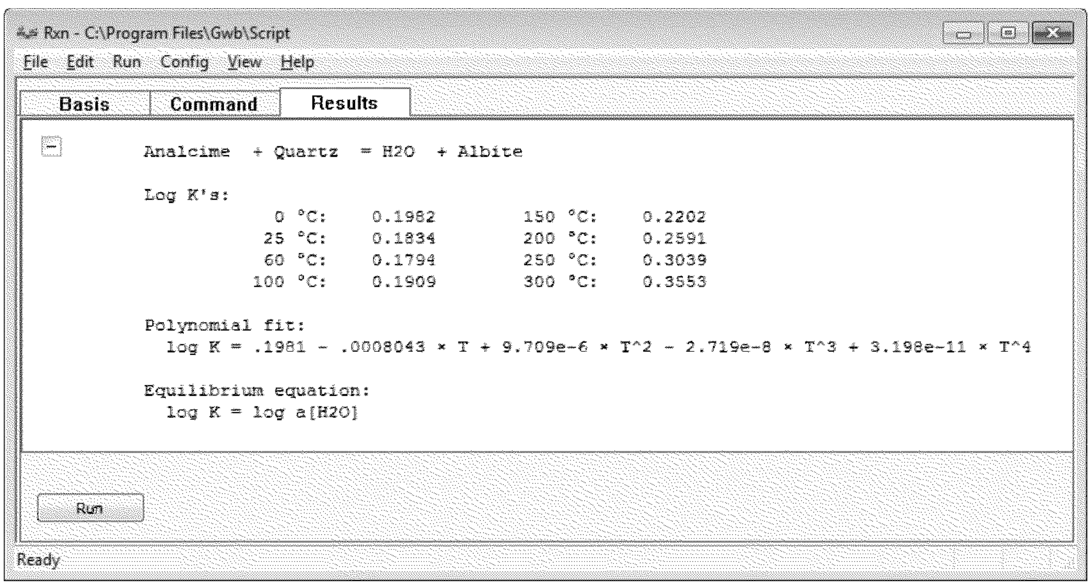
which gives the result log K = 0.3039. To unset the temperature, choose "reset" on the temperature pulldown menu, or type "T = ?".

The program can calculate additional information, including a polynomial fit that gives log K as a function of temperature from 0°C to 300°C, the equilibrium equation for the reaction under various conditions, or the temperature at which a reaction is in equilibrium. To calculate additional information, you put the program in “long” format by clicking on the + button on the Results pane, or by typing the command “long”. Return to the original “short” format by clicking on the − button, or typing “short”.

For example, unsetting temperature and setting long mode

```
(cont'd)
T = ?
long
go
```

generates the response:



You can see that at equilibrium the water activity equals the reaction’s equilibrium constant. The water activity is likely to be 1 or less, but the equilibrium constant is greater than 1 over the temperature range. The minerals albite, quartz, and analcime are unlikely, then, to be in equilibrium between 0°C and 300°C. If you set the water activity to unity on the Basis pane, or type

```
(cont'd)
a H2O = 1
go
```

the program reports in the Results pane that analcime in the presence of quartz should react to form albite:

```
Equilibrium equation:
  log K = 0
  Reaction is not in equilibrium between 0 and 300 C
    Products favored over this temperature range
```

4.1 Balancing reactions

Usingbasis swaps, youcanbalance any primary reaction. Asa nexample ofhow Rxn balances reactions by basis swapping, consider the dissolution reaction of pyrite. The steps

```
react Pyrite
go
```

give the reaction

```
Pyrite + H2O + 3.5 O2(aq) = Fe++ + 2 SO4-- + 2 H+
```

written in terms of the species in the original basis. Alternatively, you could write the reaction producing hydrogen instead of consuming dissolved oxygen:

```
(cont'd)
swap H2(aq) for O2(aq)
go
```

which gives

```
Pyrite + 8 H2O = Fe++ + 2 SO4-- + 2 H+ + 7 H2(aq)
```

Swapping dissolved H_2S for the SO_4 ion

```
(cont'd)
unswap H2(aq)
swap H2S(aq) for SO4--
go
```

gives the reaction written in terms of reduced sulfur

```
Pyrite + H2O + 2 H+ = Fe++ + 2 H2S(aq) + .5 O2(aq)
```

Finally, replacing oxygen in the basis with H_2S

```
(cont'd)
swap H2S(aq) for O2(aq)
go
```

gives a dissolution reaction written in terms of SO_4 and H_2S

```
Pyrite + H2O + 1.5 H+ = Fe++ + .25 SO4-- + 1.75 H2S(aq)
```

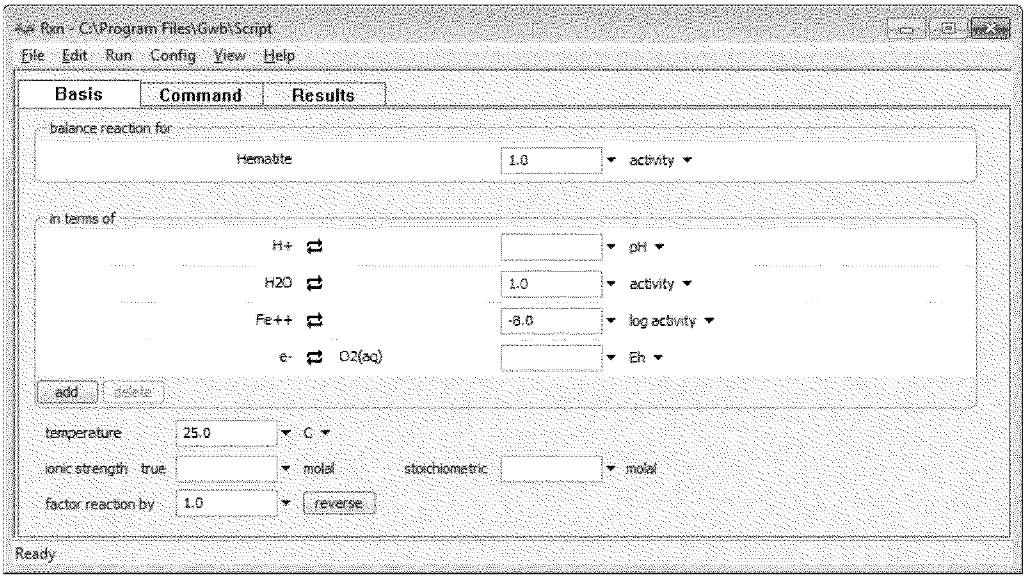
that involves neither oxygen nor hydrogen.

4.2 Calculating equilibrium equations

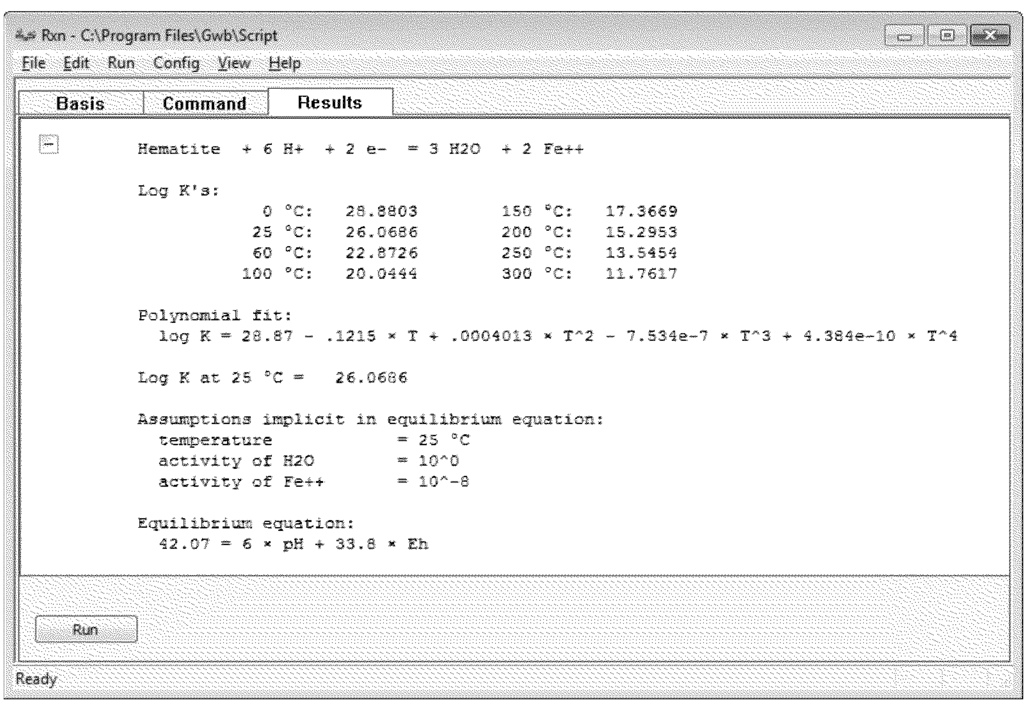
To calculate the equilibrium equation corresponding to a reaction, you constrain species activities and gas fugacities as you wish and set Rxn in long format. To calculate the line between hematite (Fe_2O_3) and Fe^{CC} in Eh-pH coordinates at 25°C, assuming an iron activity of 10 ^{8}, for example, follow the steps

```
T = 25
react Hematite
swap e- for O2(aq)
log activity Fe++ = -8
activity H2O = 1
pH = ?
Eh = ?
long
go
```

The Basis pane should look like



The result, shown on the Results pane, is



The equation can be simplified by setting “Factor reaction by” in the Basis pane to 1/6, or typing

```
(cont'd)
factor = 1/6
go
```

which gives the equilibrium equation

```
7.011 = pH + 5.634 x Eh
```

As a second exercise, we calculate at 200°C the equilibrium ratio of K^C to H^C activities for the reaction of muscovite to potassium feldspar (microcline) in the presence of quartz. Reset the configuration (select File ! Reset Configuration)and follow the steps

```
T = 200 C
react "Maximum Microcline"
swap Muscovite for Al+++
swap Quartz for SiO2(aq)
swap K+/H+ for K+
long
go
```

Rxn gives the result

```
Maximum Microcline  = .6667 K+/H+  + .3333 Muscovite + 2 Quartz

Equilibrium equation:
 2.705 = .6667*log a[K+/H+]
```

The steps

```
(cont'd)
factor = 3/2
go
```

simplify the result, giving the equilibrium activity ratio directly

```
1.5 Maximum Microcline = K+/H+ + .5 Muscovite + 3 Quartz
```

```
Equilibrium equation:
 4.057 = log a[K+/H+]
```

at this temperature.

4.3 Determining activity coefficients

You can use Rxn to calculate activity coefficients according to Debye-Hückel theory (see discussion of activity coefficients in Activity coefficients under Using SpecE8). Todo so, you specify temperature and set solution ionic strength in molal units on the Basis pane, or using the “ionic_strength” (or “I”) command. To have Rxn calculate the activity of water, you set the solution’s stoichiometric ionic strength on the Basis pane, or with the “stoich_IS” (or “SI”) command.

The steps

```
react Barite
T = 25 C
I = 3
long
go
```

cause the program to balance the reaction

```
Barite = Ba++ + SO4--
```

and report activity coefficients (“gammas”)

```
gamma for   Ba++     = 10^-.795    (I = 3 molal)
gamma for   SO4--    = 10^-.9544   (I = 3 molal)
```

for species Ba^{CC} and SO_4 in a solution of 3 molal ionic strength at 25°C. The corresponding values, expressed directly instead of in exponential form, are 0.16 and 0.11. The program gives the equilibrium equation for the reaction as

```
-8.213 = log m[Ba++] + log m[SO4--]
```

Here, Rxn has used the calculated values for activity coefficients to simplify the equation, replacing activities with species molalities.

4.4 Calculating equilibrium temperatures

Rxn cancalculatethetemperature(ortemperatures)atwhichar eactionisinequilibrium if the activity of each species and fugacity of each gas in the reaction is known. To calculate the temperature at which gypsum converts to anhydrite, you swap the two minerals into the basis and set the water activity:

```
react Gypsum
swap Anhydrite for Ca++
a H2O = 1
long
go
```

At unit water activity, the result is

```
Gypsum = Anhydrite + 2 H2O

Reaction is in equilibrium at 43.7° C
  Products favored above this temperature
```

To calculate the temperature at lower water activity (which might be appropriate for a brine), set

```
(cont'd)
a H2O = .7
go
```

The program gives the result

```
Reaction is in equilibrium at 11.8° C
  Products favored above this temperature
```

Rxn's ability to calculate equilibrium temperatures can be useful for sorting among a mineral's polymorphs to determine which is stable. For example, selecting Config ! Show... and then selecting "Albite", or typing the command

```
polymorphs Albite
```

produces a list of minerals in the database that have the same chemical formula as albite, which are "Albite high" and "Albite low". The steps

```
react Albite
swap "Albite high" for Al+++
long
go
```

generate the information that high albite is the unstable form from 0°C to 300°C.

4.5 Free energy change

When you set a temperature and constrain a reaction sufficiently that either the reactants or reaction products are favored thermodynamically, Rxn will report the corresponding free energy change of reaction.

As an example, the commands

```
react CH3COO-
swap CH4(aq) for O2(aq)
log activity CH3COO- = -6
log activity HCO3- = -3
log activity CH4(aq) = -6
activity H2O  =  1
T = 25 C
long
go
```

set Rxn to balance the reaction for the dismutation of acetate ion at 25°C, assuming bicarbonate is present at mmol/kg, and acetate and methane at ┬mol/kg levels.

On the Results pane the program reports the acetoclastis reaction

```
CH3COO-  + H2O  = HCO3-  + CH4(aq)
```

along with the result

```
Equilibrium equation:
  Products are favored, delta G = -32.2 kJ/mol
```

that the reaction has a modest thermodynamic drive to proceed forward.

4.6 Sorption reactions

Rxn manipulates the reactions by which ions sorb to a mineral in the same way it handles other types of reactions. You access a dataset of surface reactions by selecting File ! Open ! Sorbing Surfaces... and then clicking on add, or with the "surface_data" ("surf_data") command. Once entered, you can view the surface sites and complexes by selecting Config ! Show..., or typing "show surfaces".

4.6.1 Surface complexation

For the two-layer surface complexation model, you read a dataset of complexation reactions, such as "FeOH.sdat" supplied with the GWB. The steps

```
surf_data FeOH.sdat
react >(s)FeOPb+
pH = ?
long
go
```

for example, cause Rxn to report the reaction

```
>(s)FeOPb+  + H+  = >(s)FeOH  + Pb++
```

and its corresponding equilibrium equation

```
log K + (F PSI[HFO]/2.303 RT) = - log m[>(s)FeOPb+]
      + log m[>(s)FeOH] + pH + log a[Pb++]
```

The second term in the equation is the logarithm of the Boltzman factor, which accounts for electrostatic forces between the surface and solution. Here, "F" is the Faraday constant, "PSI" is mean surface potential, "R" is the gas constant, and "T" is absolute temperature; "m" represents molal concentration.

Rxn will evaluate the Boltzman factor numerically if you specify temperature and ionic strength (on the Basis pane), and the charge density on the sorbing surface. You provide the latter value on the Sorbing Surfaces dialog (File ! Open ! Sorbing Surfaces...), or with the "surface_charge" (or "surf_charge") command, in units of ┬ C/cm^2. Continuing from above, the steps

```
(cont'd)
T = 25 C
I = 0.1
```

```
surf_charge = -10
go
```

give the simplified equation

```
-5.706 = - log m[>(s)FeOPb+] + log m[>(s)FeOH]
       + pH + log m[Pb++]
```

corresponding to25 °C, an ionic strength of 0.1molal, and asurfacecharge density of 10┬ C/cm^2.

Theconstantcapacitance andconstantpotential modelsare variantsofthesurface complexation model. You set these on the Sorbing Surfaces dialog (File ! Open ! Sorbing Surfaces. . .), or using the “surface_capacitance” and “surface_potential” commands, as described in the Configuring the Programs chapter.

4.6.2 Ion exchange

As described in the Configuring the Programs chapter, you can model ion exchange in two ways. The first method is to swap an activity ratio into the basis. This method is equivalent toassuming that there exists a sufficiently large reservoir of exchanging ions that the composition of the exchanging surface remains invariant.

For a more general treatment, you prepare a small dataset of exchange reactions, using file “IonEx.sdat” as a template. You load a dataset of exchange reactions by selecting File ! Open ! Sorbing Surfaces. . . , or with the “surface_data” (or “read”) command. The exchange reactions in this dataset are now available to your Rxn session.

You can load one or more exchange datasets (containing one or more exchange reactions) at a time, and in a single run combine ion exchange datasets with other types of surface reaction datasets.

4.6.3 Distribution coefficients (K_d’s)

To use distribution coefficients (K_d’s) to model sorption, you prepare one or more datasetscontainingthesorptionreactions andcorrespond ing distributioncoefficients, using file “Kd.sdat” as a template (see the Configuring the Programs chapter). As withany sorption model, youread thedataset(s) byselectin g File ! Open ! Sorbing Surfaces. . . , or using the “surface_data” command. Once the dataset(s) have been read, the sorption reactions they contain are available to your Rxn session.

In the distribution coefficient model, the concentration of a sorbed ion is carried in units of moles per gram solid. If you wish to constrain the sorbed concentration of an ion in Rxn, therefore, you do so in units of mol/g using the “sorbed_mass” (rather than the “molality”) command.

4.6.4 Freundlich isotherms

The use of Freundlich isotherms is broadly similar in implementation to the K_d approach, as described in the previous section, except the dataset of surface reactions follows the format of “Freundlich.sdat”, rather than “Kd.sdat”.

4.6.5 Langmuir isotherms

To model sorption according to Langmuir isotherms, you prepare a dataset containing the sorption reactions, in the format of dataset “Langmuir.sdat”, which is distributed as a template with the GWB.

You enter the dataset into an Rxn run by selecting File ! Open ! Sorbing Surfaces. . . , or with the “surface_data” (or “read”) command. You can enter one or more Langmuir datasets, and mix Langmuir datasets with datasets for other sorption methods

4.7 Rxn command line

You can start Rxn by clicking the icon under the “Start” menu, opening a “.rxn” file, or by entering the command “rxn.exe” from the Windows “Command Prompt”.

When you start Rxn from the command line (as opposed to clicking on the icon), you can specify a number of arguments. For example, the command

```
rxn -i my_script -d my_thermo.tdat
```

causes Rxn to read input commands from a file “my_script”, and to use “my_ thermo.tdat” as the thermodynamic database.

The following options are available from the command line:

-cd	Change the working directory to the directory containing the input script specified with the -i option.
-d <thermo_data>	Set the file of thermodynamic data to be used.
-i <input_script>	Set a file from which to read input commands.
-pipe <pipe_name>	Set a pipe named pipe_name from which other programs can run Rxn by remote control. Rxn accepts input commands from the pipe, and writes output to it. If pipe_name is “stdio”, the pipe is unnamed and uses the standard input and output data streams.
-s <sorp_data>	Set the file of surface sorption reactions to be used.

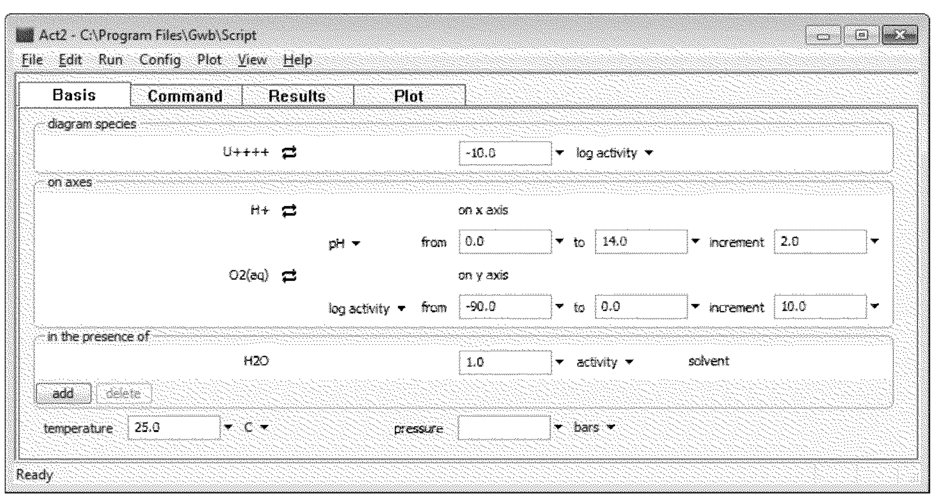
Using Act2

Act2 is a program that calculates and plots activity-activity diagrams. This class of diagrams shows the stability of minerals and predominance of aqueous species in chemical systems. A species activity, gas fugacity, activity or fugacity ratio, pH, Eh, or pe may serve as an axis variable.

Start Act2 from the GWB dashboard, or by opening a ".ac2" file.

To diagram the effects of pH and the activity of dissolved oxygen on the speciation of uranium in water, for example, you start the program and select "U++++" under "Diagram species". To do so, click on the current setting, initially "???", to show the choice of basis entries available to diagram (remember that touching U moves down the list to "U++++"). To the right, change the units by selecting "log activity", then enter "-10" for the species' log activity.

In the box below, select "H+" for the x-axis species, and "O2(aq)" for the y-axis. Then set "pH" as the unit for the x-axis and adjust the y-axis range. The Basis pane should look like this:



Alternatively, enter the commands

```
diagram U++++ on O2(aq) vs pH
log a U++++ = -10
x from 0 to 14; y from -90 to 0
```

Here we have set a uranium activity of 10^{10} and, by default, a temperature of 25°C. You specify axis ranges in terms of the logarithms of activity or fugacity values, and hence linearly in terms of pH, pe, and Eh. Move to the Plot pane or type "go" in the Command pane to display the result.

The program produces a file "Act2_output.txt" describing the calculation (select File ! View ! Act2_output.txt to inspect this dataset) and displays the diagram on the Plot pane. Figure 5.1 (a) shows the resulting plot. (Note that many of the figures in the Users Guide have been simplified slightly or relabeled to allow for reduction and printing.) You can return to the Basis or Command pane to alter the program configuration and produce further diagrams.

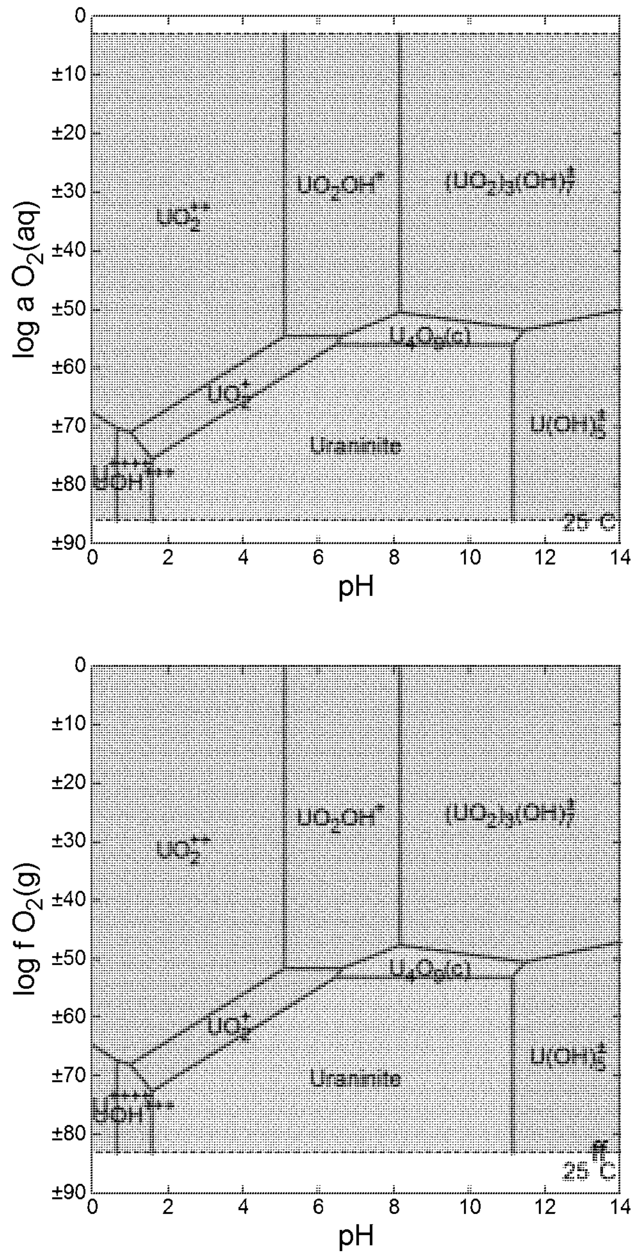
To plot the fugacity of oxygen gas along the vertical axis on the diagram we just calculated, move to the Basis pane and swap the gas species into the basis by clicking on the ⇄ next to the y-axis entry; then move to the Plot pane. This is equivalent to entering the commands

```
(cont'd)
swap O2(g) for O2(aq)
y from -90 to 0
go
```

Swapping the electron into the basis allows you to plot oxidation state in terms of Eh. On the Basis pane, swap the "e-" for "O2(aq)", set units of "Eh", and move to the Plot pane. Equivalent commands are:

```
(cont'd)
swap e- for O2(aq)
diagram on Eh
y from -.75 to 1.25
go
```

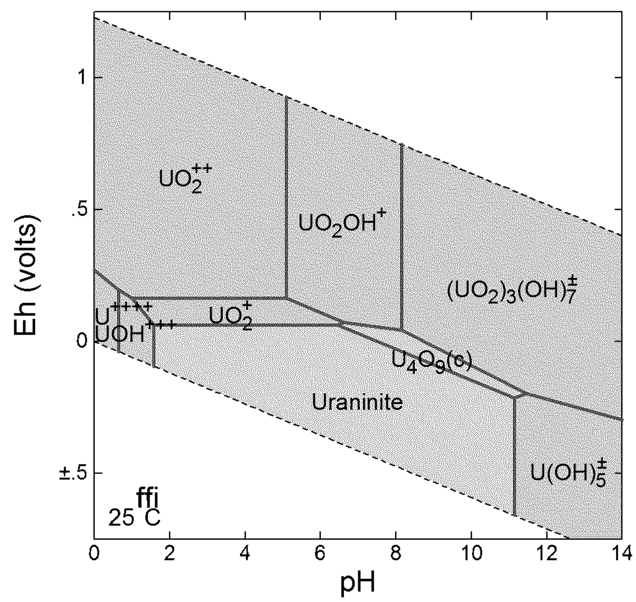
The oxidation state can be also represented in terms of the log activity ratio of a redox pair such as ferrous and ferric iron. On the Basis pane, click on ⇄ next to the y-axis entry and select "Ratio". Set "Fe+++" with a power of one as the numerator species, and "Fe++" with the same power in the denominator:



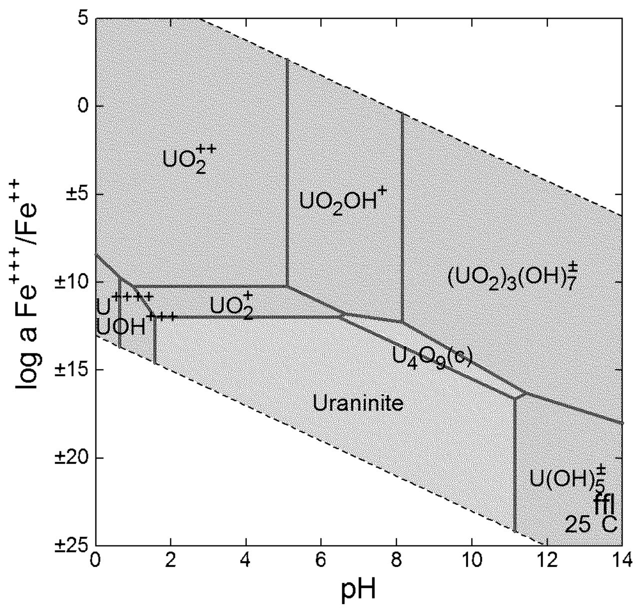
(a)

(b)

Figure 5.1 Redox-pH diagrams for uranium drawn at 25°C and a species activity of 10^{-10}. Diagrams are plotted against the redox variables (a) activity of dissolved oxygen, (b) fugacity of oxygen gas.

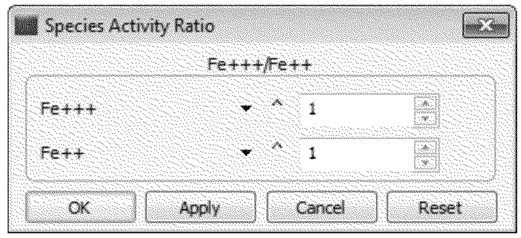


(c)



(d)

Figure 5.1 (continued) (c) Eh, and (d) the activity ratio of Fe^{+++} to Fe^{++}. Dashed lines show stability limits of water at 1 atm pressure.



To the right of this entry in the Basis pane, set the axis to range from "–25" and "5" and move to the Plot pane. Alternatively, enter the commands

```
(cont'd)
swap Fe+++/Fe++ for O2(aq)
y from -25 to 5
go
```

Figure 5.1 (b–d) shows the results of these calculations.

Incalculatingadiagram, Act2 balances eachreactionpossibleamongtheaqueous species and minerals in the system and lists them along with their equilibrium equations in the "Act2_output.txt" dataset.

5.1 Diagram calculation

The most familiar class of activity-activity diagram is the redox-pH, but Act2 can calculate diagrams on any activity or fugacity axis, as well as diagrams that account for the presence of minerals, complexing species, and gas buffers.

To evaluate the effect at 60°C of chloride complexing on copper at a CO_2 fugacity of 1, for example, you could set the Cl activity and CO_2 fugacity in your input. The steps to calculate such a diagram are:

```
T = 60
diagram Cu+ on O2(aq) vs pH
x from 0 to 14
y from -80 to 0
swap CO2(g) for HCO3-
log a Cu+ = -6
a Cl- = 0.1
f CO2(g) = 1
```

The effect might be shown better by drawing the diagram at a pH of 6 using the activity of Cl as an axis:

```
(cont'd)
diagram vs Cl-
pH = 6
x -3 .5
```

Figure 5.2 shows the diagrams resulting from these steps.

A number of simple aluminosilicate minerals can be formed from kaolinite by exchanging cations for protons and adding or removing silica. The diagram defined by the following steps shows the stability of potassic and calcic aluminosilicates in the presence of quartz (Figure 5.3 (a)).

```
swap Kaolinite for Al+++
swap Quartz for SiO2(aq)
swap K+/H+ for K+
swap Ca++/H+^2 for Ca++
diagram Kaolinite on K+/H+ vs Ca++/H+^2
x 12 20; y 2 9
```

To show the effect of varying the silica activity, replace the x-axis with $a_{SiO_2.aq/}$

```
(cont'd)
unswap Quartz
diagram vs SiO2(aq)
remove Ca++/H+^2
x -5 -2; y -5 10
```

The results are shown in Figure 5.3 (b).

5.2 Solubility diagrams

Solubility diagrams are similar to the diagrams calculated to this point, except that the activity of the main species, instead of being set to a constant value, appears as an axis variable.

To calculate the solubility of U^{CCCC} versus pH, for example, you follow the steps

```
diagram U++++ on U++++ vs pH
x from 0 to 14
y from -16 to -6
```

Similarly, the steps

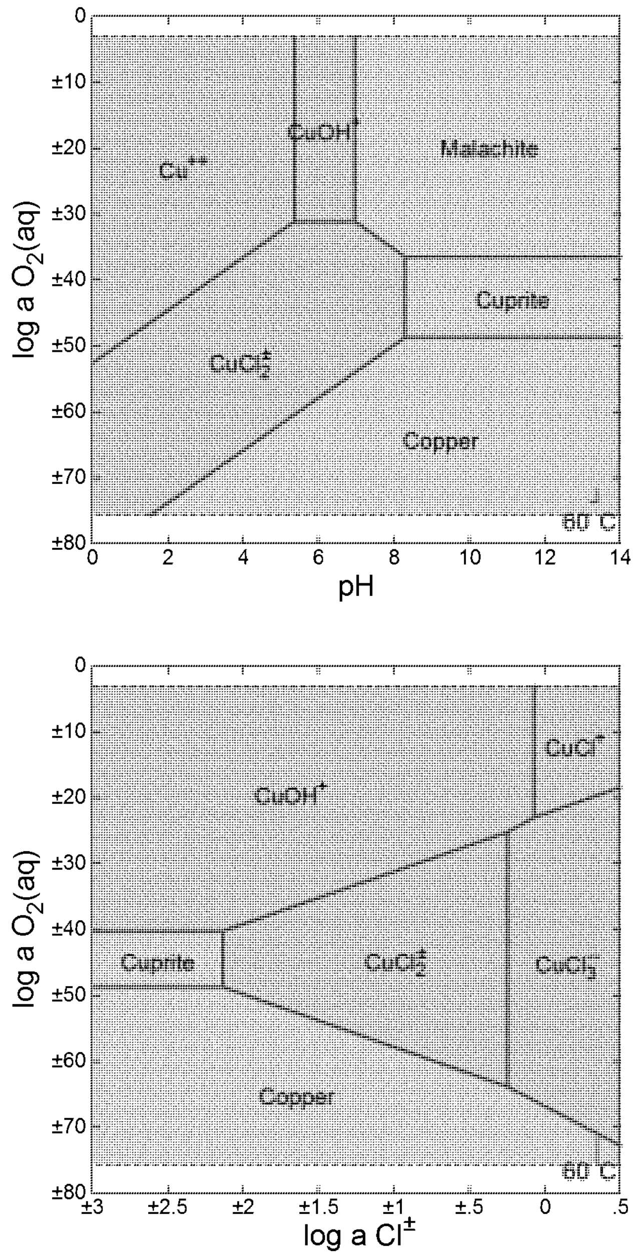
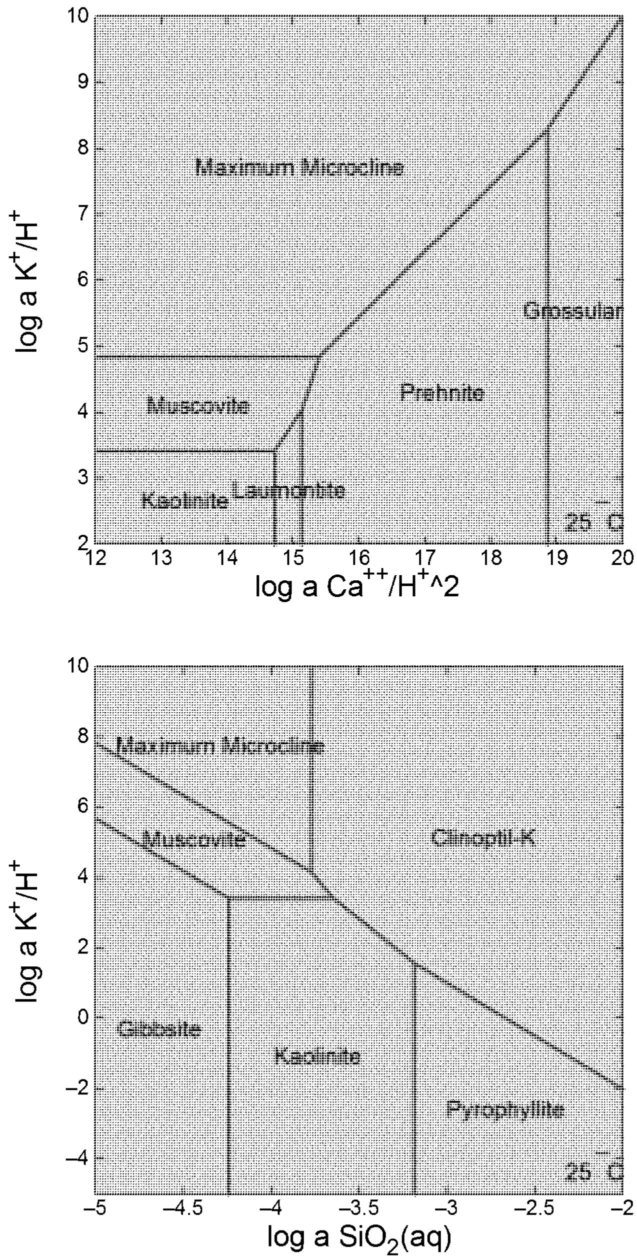


Figure 5.2 Activity-activity diagrams drawn at 60°C for the copper-CO_2-chlorine system at f_{CO_2} D 1 versus oxygen activity and (a) pH at a_{Cl^-} D .1, and (b) a_{Cl^-} at pH D 6. Note in (a) the implausibility of maintaining in nature this CO_2 fugacity under alkaline conditions.



(a)

(b)

Figure 5.3 Stability diagrams for aluminosilicate minerals at 25°C (a) plotted versus a_{K^+}/a_{H^+} and $a_{Ca^{++}}/a^2_{H^+}$ in the presence of quartz, and (b) versus a_{K^+}/a_{H^+} and $a_{SiO_2(aq)}$.

```
T = 60 C
swap Quartz for SiO2(aq)
diagram Al+++ on Al+++ vs pH
x from 3 to 8 incr 1/2
y from -8 to -5 incr 1/2
```

produce a diagram showing the solubility of Al^{CCC} as a function of pH at 60°C in the presence of quartz. Figure 5.4 shows the resulting solubility diagrams.

5.3 Mosaic diagrams

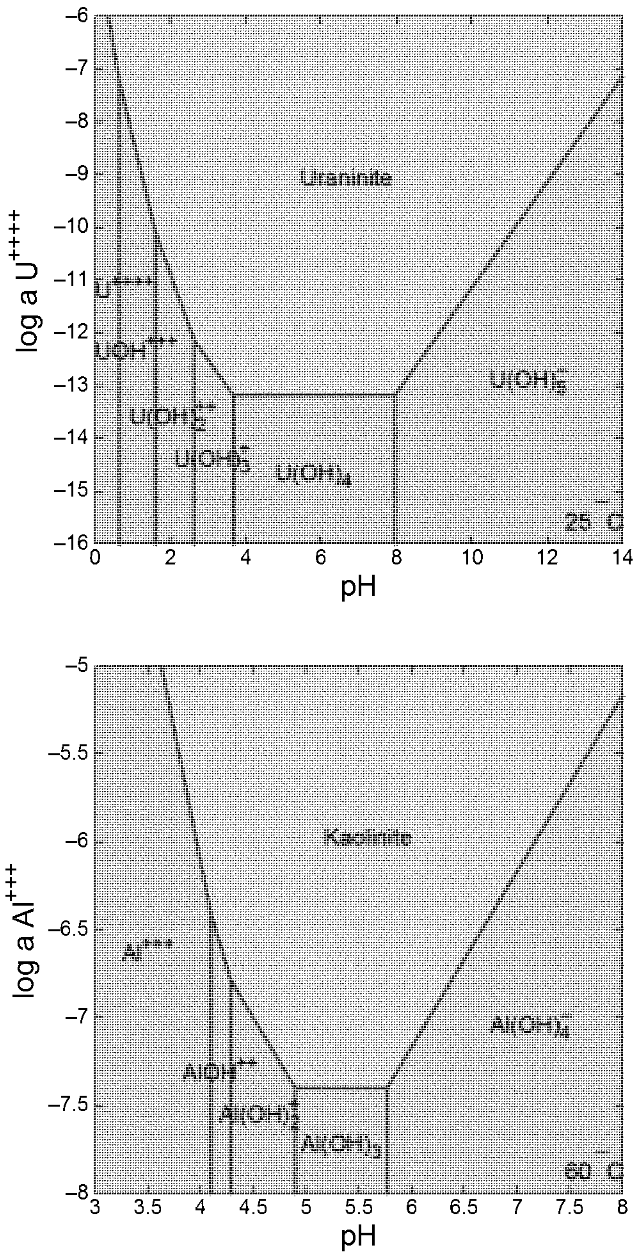
Calculating diagrams that include complexing ions is complicated in some cases by the speciation of the ions over the diagram axes. For example, while the bicarbonate ion HCO_3 is important at moderate pH values, it reacts under acidic conditions to form CO_2(aq) and under alkaline conditions to form CO_3 . Similarly, the sulfate ion SO_4 occurs in acidic waters as HSO_4 and under reducing conditions as H_2S(aq), HS , and S ; NO_3 is found in the reduced forms HNO_2, NO_2, N_2, NH_4^C and NH_3; and HPO_4 reacts depending on pH to form H_3PO_4, H_2PO_4, and PO_4^3 .

Insuch cases, Act2 can calculate mosaic diagrams in which the overall calculation is divided into subdiagrams, each in which a single form of a complexing species predominates. Assembled,thesubdiagrams formthecomplet ediagram.Theprogram allows any number of the complexing ions to speciate. Each ion may speciate by reaction with the species on both of the axes, or the x-axis or y-axis alone.

You set a mosaic diagram by adding a species to the diagram, using the add button on the Basis pane, in the "in the presence of" section. Then, under the corresponding units pulldown, select to speciate that species over x, y, or both x and y. Alternatively, you can use the "speciate" command.

The following example, using the chemistry of the arsenic-sulfur system, shows the importance of the mosaic diagram. The steps

```
T = 100 C
diagram As(OH)4- on O2(aq) vs pH
x from 0 to 14
y from -70 to -40
log a As(OH)4- = -3
log a SO4-- = -4
speciate SO4--
```



(a)

(b)

Figure 5.4 Solubility diagrams versus pH for (a) uraninite at 25°C, and (b) kaolinite at 60°C.

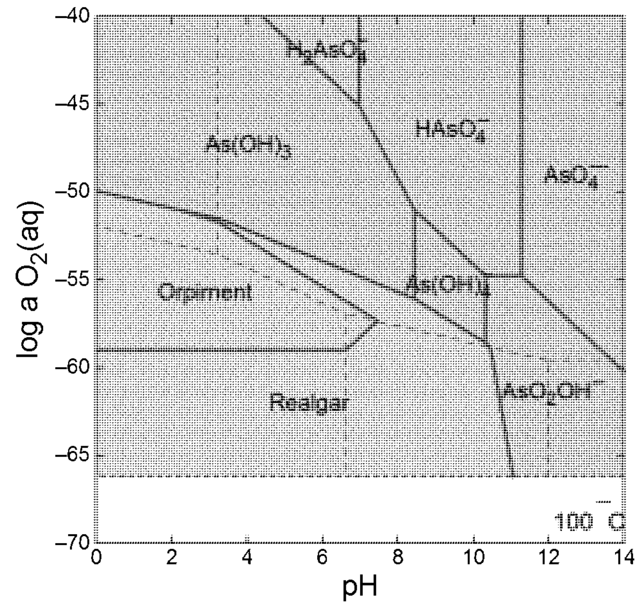


Figure 5.5 Mosaic diagram for the arsenic-sulfur system drawn at 100°C versus oxygen activity and pH, assuming an arsenic species activity of 10 ^{3} and sulfur species activity of 10 ^{4} Interior broken lines show mosaic boundaries for sulfur speciation. Subdiagrams in the mosaic, from upper left to lower right, are for the species HSO_4 , SO_4 , H_2S(aq), HS , and S . Basal broken line is stability limit for water under reducing conditions at 1 atm pressure.

result in a diagram (Figure 5.5) predicting the importance of the sulfide minerals orpiment (As_2S_3) and realgar (AsS) under reducing conditions.

Note that if we had not made a mosaic diagram but had instead assumed that SO_4

```
(cont'd)
unspeciate SO4--
go
```

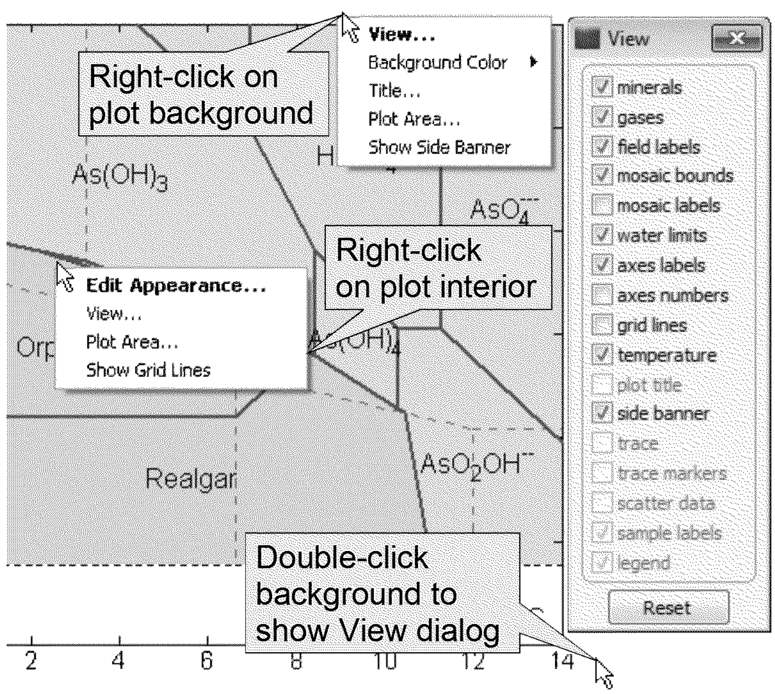
or HS

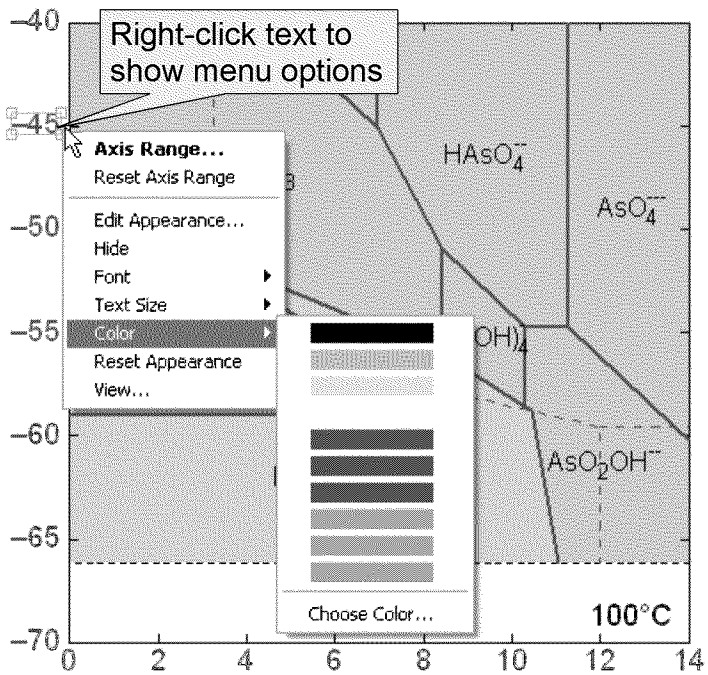
```
(cont'd)
swap HS- for SO4--
go
```

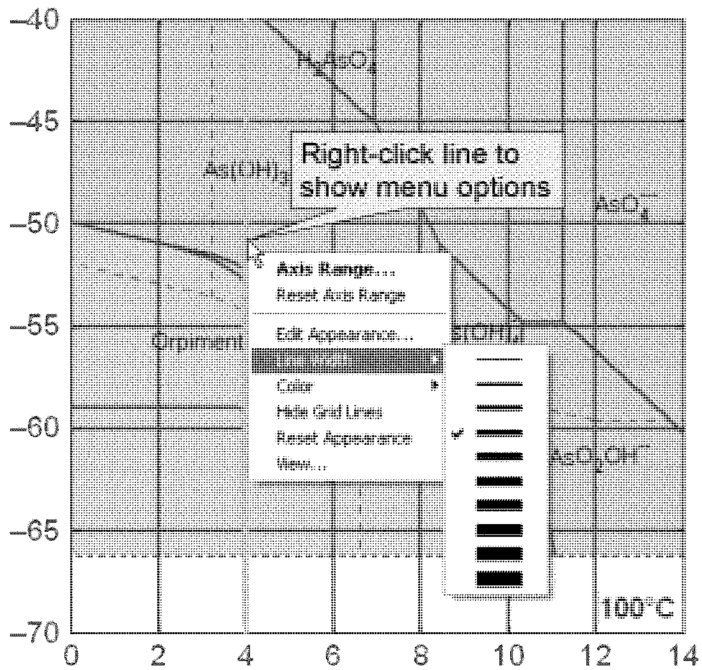
predominates over the entire diagram, the result would be significantly in error.

5.4 Editing plot appearance

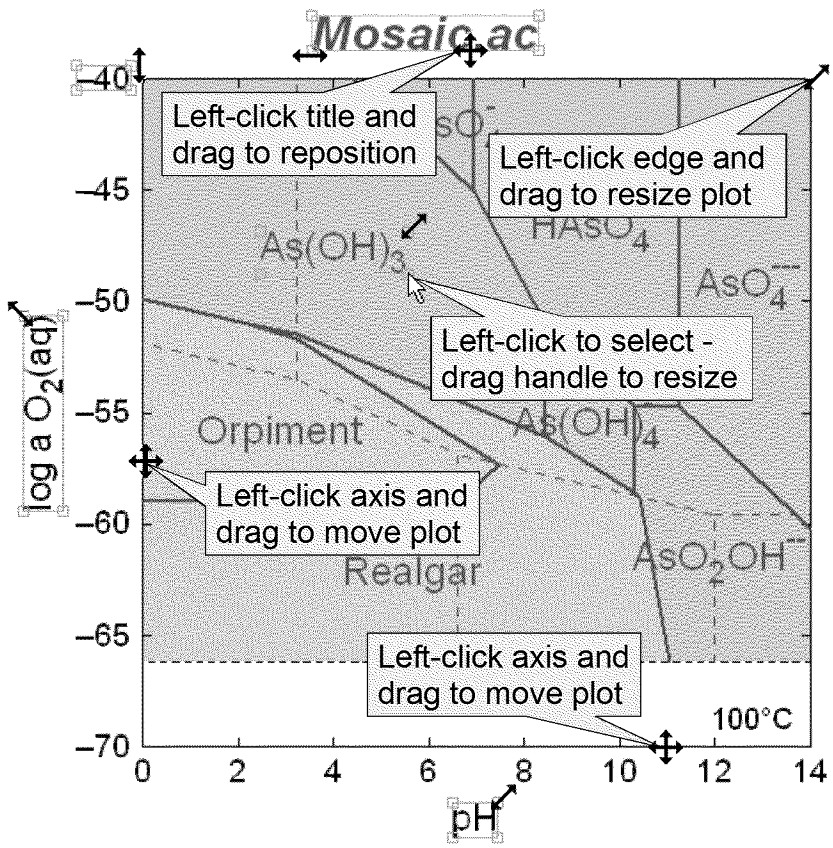
In Act2 you can interactively modify many aspects of the diagram. A right-click on an aspect or area of the plot displays a menu showing the options available. You may choose to reset an axis range or an aspect's appearance to its default state. A double-click on an aspect brings up a dialog box related to the first item on the pulldown menu, which in most cases is the aspect's appearance dialog. The dialogs can also be accessed through the Plot menu. To change the font for individual aspects, choose Font from that aspect's menu. A double-click on the background area will bring up the View... dialog, which lets you select the graphical elements to be shown.

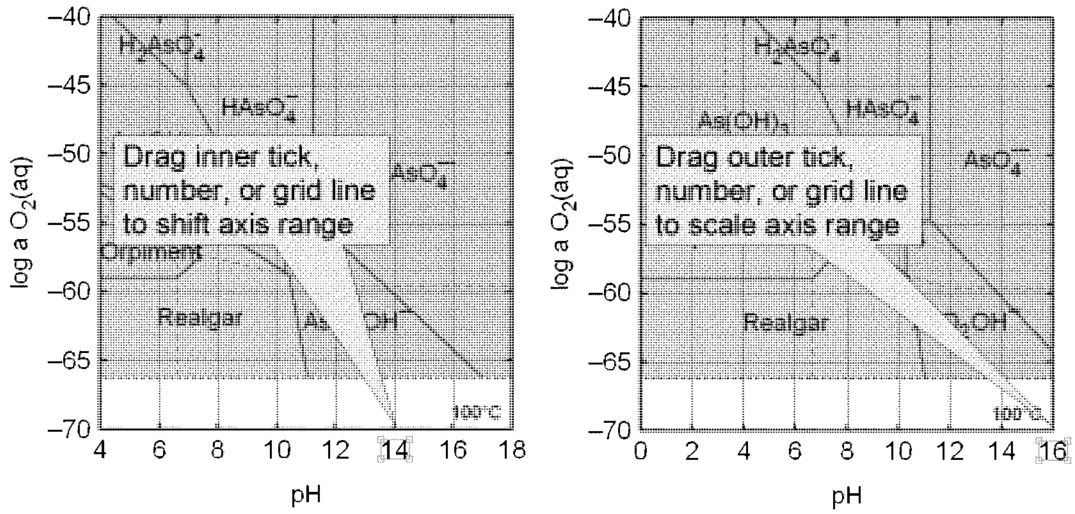



Right-click text to show menu options
Axis Range...
Reset Axis Range
Edit Appearance...
Hide
Font
Text Size
Color
Reset Appearance
View...
Choose Color...
HAsO4--
AsO4---
AsO2OH--
100°C
-40
-45
-50
-55
-60
-65
-70
0
2
4
6
8
10
12
14


Right-click line to show menu options
Axis Range...
Reset Axis Range
Edit Appearance...
Color
Hide Grid Lines
Reset Appearance
View...
As(OH)3
Orpiment
AsO4
AsO2OH
100°C
-40
-45
-50
-55
-60
-65
-70
0
2
4
6
8
10
12
14

A left-click on an aspect causes it to be "selected". An aspect has been selected whenitscolorchanges,asinthecaseoflines,orwhenitissu rroundedbymanipulation handles, in the case of text or markers. Change the size of text,markers, and the plot itselfby dragging thesizingcursors. Adjust theplacement of theplot by clickingwithin the plot or on either axis and dragging it. The plot title canb e moved inthe same way.

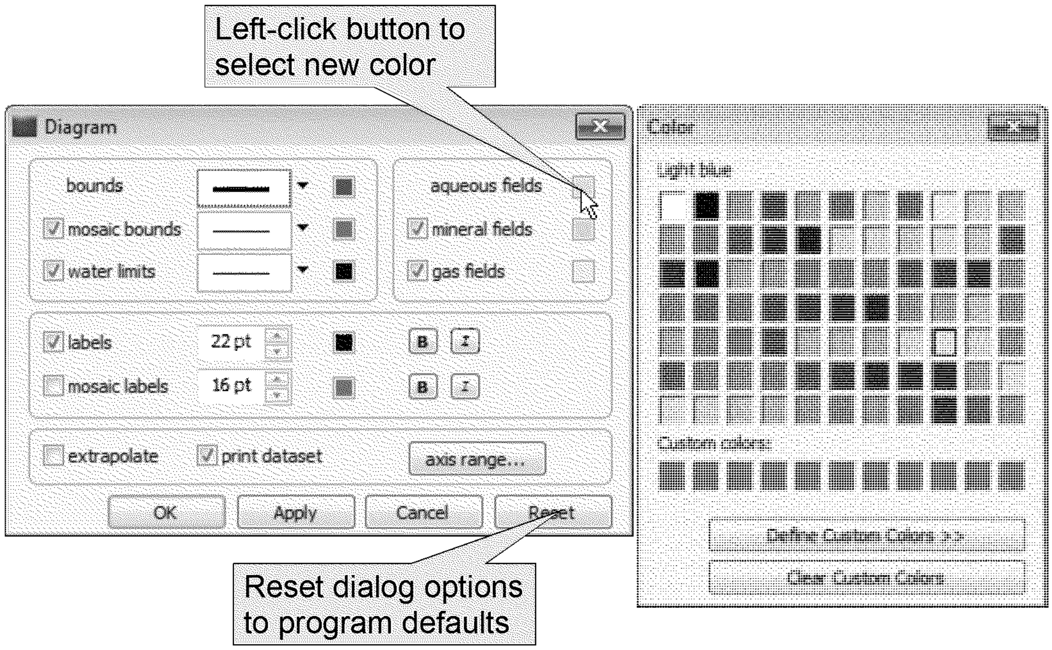




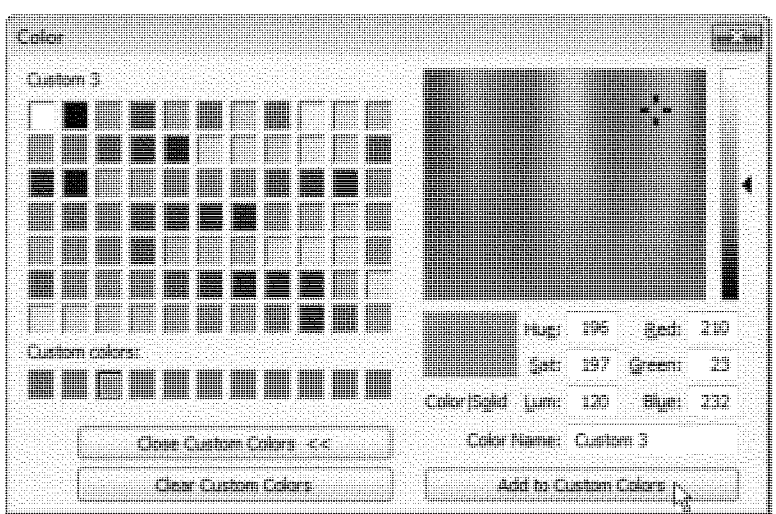
You can change the range on an axis by clicking and dragging a tick mark, number, or grid line. Dragging a tick within an axis shifts all of the values along the axis, effectively changing the minimum and maximum values at the ends of the axis, but keeping the spacing the same. Dragging the tick at an end of an axis changes the minimum or maximum value. To reset the axis range to span the range of the data being plotted, choose Reset Axis Range from the aspect menu.

Youcansetallofthegraphicalattributesintheaspectappe arance dialogs available through the Plot menu. When you make changes tovalues or selections inan aspect appearance dialog, the changes don't take effect on the plot immediately. You may set up your choices for as many of the aspects as you like, or use the "Reset" button to reset the dialog to its default values. Use the "Apply" or "OK" button to apply the changes to the plot. Use the "Cancel" button if you decide that you don't want the changes applied.

Selecting Color ! Choose Color... from any aspect menu or clicking on any color button in anaspect appearance dialog allows you toset the color of therelevant aspect. The Color dialog initially presents a selection of named colors to choose from, with the current color of the aspect highlighted.



You may create custom colors. To do so, in the Color dialog double-click any of the named colors or click on "Define Custom Colors". This displays the extended version of the dialog through which you can create a custom color. Once you are satisfied with the color you have created, you may give it an optional color name, then choose "Add to Custom Colors". The color is then available, just like any of the other named colors.



5.5 Reaction traces

Act2 can overlay onto a diagram the trace of a reaction path calculated with the React program, or a scatter plot of data points. To project the trace of a reaction, first use React, as described in Using React in the GWB Reaction Modeling Guide, to calculate the reaction path. React produces an output dataset "React_plot.gtp", which Act2 can read.

Within Act2, select File ! Open ! Reaction Trace... to select a ".gtp" file produced by a previous React run. Alternatively, you can type the command

```
trace dataset_name
```

where dataset_name is the path to the "React_plot.gtp" file.

To change the default line width, colors, and size (in points) of the markers on the trace, use the "line" command from the Act2 prompt:

```
line trace x-fine blue
line markers size = 30
```

or the Trace... dialog from the Plot pulldown on the graphics window.

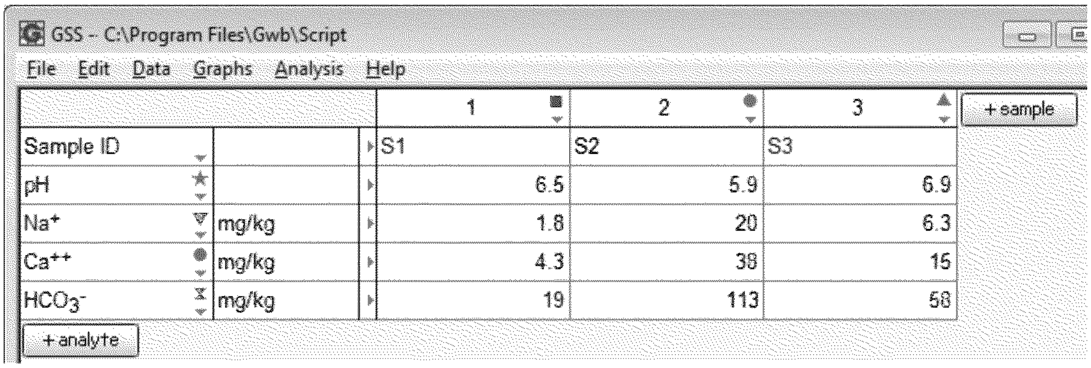
5.6 Scatter data

You can overlay the data points in a GSS data sheet (a .gss file) as "scatter data" on your Act2 diagram. First, check that the .gss file contains the axis variables on your diagram: pH, Eh, pe, species activity, or gas fugacity; or the activities of the original basis entries in the thermo dataset, so Act2 can figure these values.

Remember that Act2 diagrams are plotted in terms of species' activities and fugacities, not chemical concentrations. You can quickly add activities and fugacities to your .gss files as "calculated analytes," as described in the Calculating analytes section of the Using GSS chapter in this guide.

Even if your data sheet contains O_2(aq) concentration in mg/kg, for example, it would have to include as well the activity of O_2(aq), in order for the data to appear on a log a O_2-pH diagram. You add O_2(aq) activity to your data sheet as a calculated analyte, then, separate from the dissolved oxygen measurements.

An example of a .gss dataset containing Act2 scatter data is



To read a .gss file into Act2, click on File ! Open ! Scatter Data. . . . The program will read the data points and project them onto the diagram. The Act2 command

```
scatter dataset_name
```

serves the same purpose. Clear scatter data from a diagram on the Open ! Scatter Data. . . dialog, with the OFF button.

The marker representing each sample in the scatter data is set in the .gss file. In GSS, right-click on a sample to change the marker used, and its color and size. When you modify a .gss file, you must save it and reload it in Act2, using the Open dialog or "scatter" command, to see the changes. To add error bars to the scatter points, enter triplets, like 0.5|2.0|3.5, in the data cells (see Error bars in Using GSS).

You can label each data point with the sample's "Sample ID", as set in the .gss file, and display a legend showing the symbols used. In Act2, choose Plot ! GSS Data. . . and under "Labels" select the checkbox for "Sample" to show sample labels, and the "Legend" box to display the legend. Use the Plot ! View. . . dialog to quickly toggle on and off display of the scatter data, data labels, and legend.

In GWB releases 7.0 and earlier, the program took scatter data from a specially formattedtextfile,ratherthana.gssdatasheet.Legacysca tterfilesarestillsupported and described in the Scatter Data appendix in the Reference Manual.

5.7 Act2 command line

You can start Act2 by clicking the icon under the "Start" menu, opening a ".ac2" file, or entering the command "act2.exe" from the Windows "Command Prompt."

When you start Act2 from the command line (as opposed to clicking on the icon), you can specify a number of arguments. For example, the command

```
act2 -i my_script -d my_thermo.tdat
```

causes Act2 to read input commands from a file “my_script”, and to use “my_thermo.tdat” as the thermodynamic database.

The following options are available from the command line:

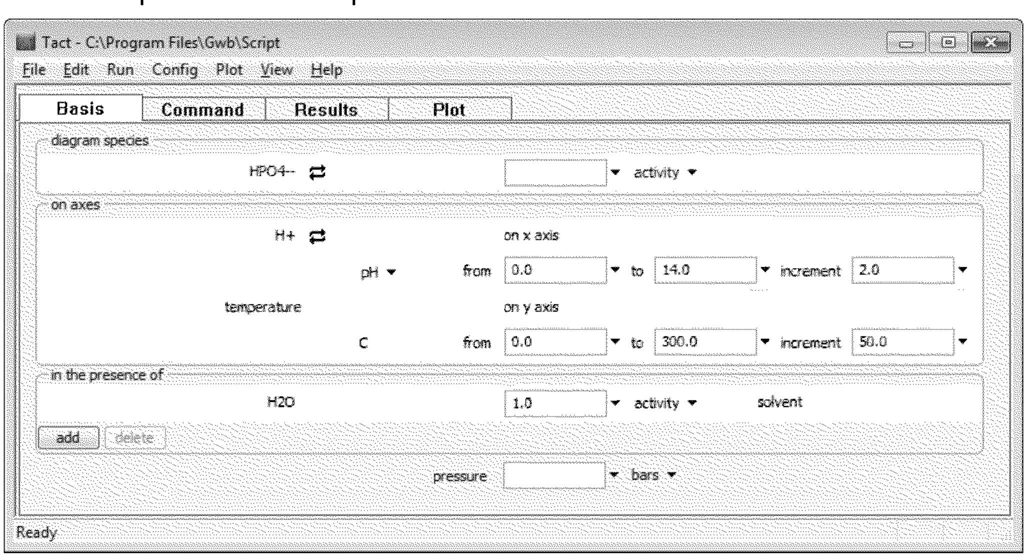
-cd	Change the working directory to the directory containing the input script specified with the -i option.
-d <thermo_data>	Set the file of thermodynamic data to be used.
-i <input_script>	Set a file from which to read input commands.
-pipe <pipe_name>	Set a pipe named pipe_name from which other programs can run Act2 by remote control. Act2 accepts input commands from the pipe, and writes output to it. If pipe_name is “stdio”, the pipe is unnamed and uses the standard input and output data streams.

Using Tact

Tact is a program that calculates and plots temperature-activity and temperature-fugacity diagrams. Diagrams of this type show the effect of temperature on the stability of minerals and the predominance of aqueous species in chemical systems. Tact is very similar to Act2, except that the vertical axis represents temperature instead of an activity or fugacity.

Start Tact from the GWB dashboard, or by opening a ".tac" file.

To diagram, for example, the thermal stability of phosphate species versus pH, you follow the same steps you would use in Act2, except that you need not specify a variable for the y axis. Under "Diagram species" on the Basis pane, click on "???" (or any species there already), select HPO_4 , and then set the species' log activity to -3. Under "On axis", click on "???", choose "H+", and set units to "pH". The Basis pane should look like this:



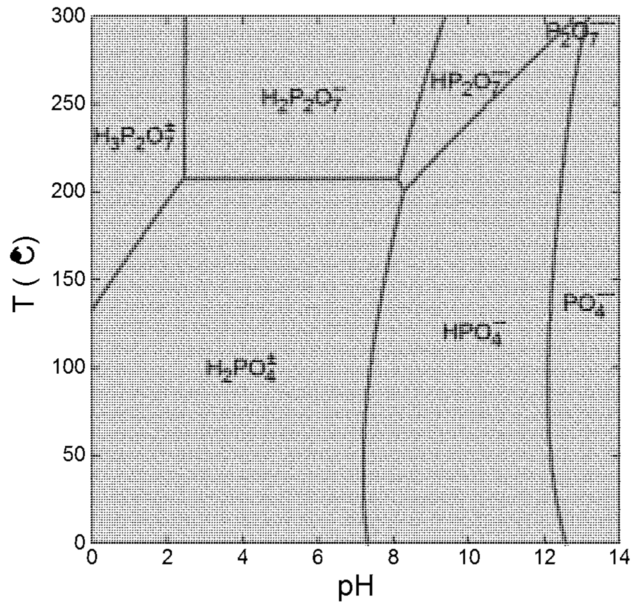


Figure 6.1 Diagram showing predominance of phosphate species versus temperature and pH.

Alternatively, enter the commands

```
diagram HPO4-- vs pH
a HPO4-- = 10^-3
x from 0 to 14
```

on the Command pane. Now move to the Plot pane or type go on the Command pane to display the resulting diagram (Figure 6.1). The program also produces text output in dataset “Tact_output.txt” (click on File ! View ! Tact_output.txt).

6.1 Diagram calculation

Tact, like Act2, can assume any activity or fugacity variable on the x axis and can account for the presence of minerals, complexing species, and gas buffers.

For example, to calculate the stabilities of aluminosilicate minerals versus SiO_2(aq) activity in a system of known ratios $a_{Ca\,C\,C}=a^2_{H\,C}$ and $a_{K\,C}=a_{H\,C}$, follow the steps

```
swap Kaolinite for Al+++
swap Ca++/H+^2 for Ca++
swap K+/H+ for K+
diagram Kaolinite vs SiO2(aq)
log ratio Ca++/H+^2 = 10.5
log ratio K+/H+ = 3.5
x from -4.5 to -1.5 incr 1/2
y from 0 to 200
```

To diagram the same system with the SiO_2(aq) activity fixed by equilibrium with tridymite, and the $a_{Ca\,C\,C}=a^2_{H\,C}$ ratio as the axis variable, continue with the steps

```
(cont'd)
diagram vs Ca++/H+^2
swap Tridymite for SiO2(aq)
x from 8 to 16
```

Figure 6.2 shows the resulting diagrams.

As a second exercise, diagram the equilibrium point of the souring reaction of natural gas

$$\text{Anhydrite}\,C\,CH_4.g/\ \ !\ \ \text{Calcite}\,C\,H_2O\,C\,H_2S.g/ \tag{6.1}$$

in terms of the fugacity ratio of methane to H_2S:

```
swap Calcite for Ca++
swap H2S(g)/CH4(g) for SO4--
diagram Calcite vs H2S(g)/CH4(g)
x-axis from -15 to 10
```

Figure 6.3 shows the resulting plot.

6.2 Solubility diagrams

Toconstruct asolubility diagram, you specify themain species as the x-axis variable. To plot the solubility of quartz [in terms of SiO_2 activity],for example, set the program to

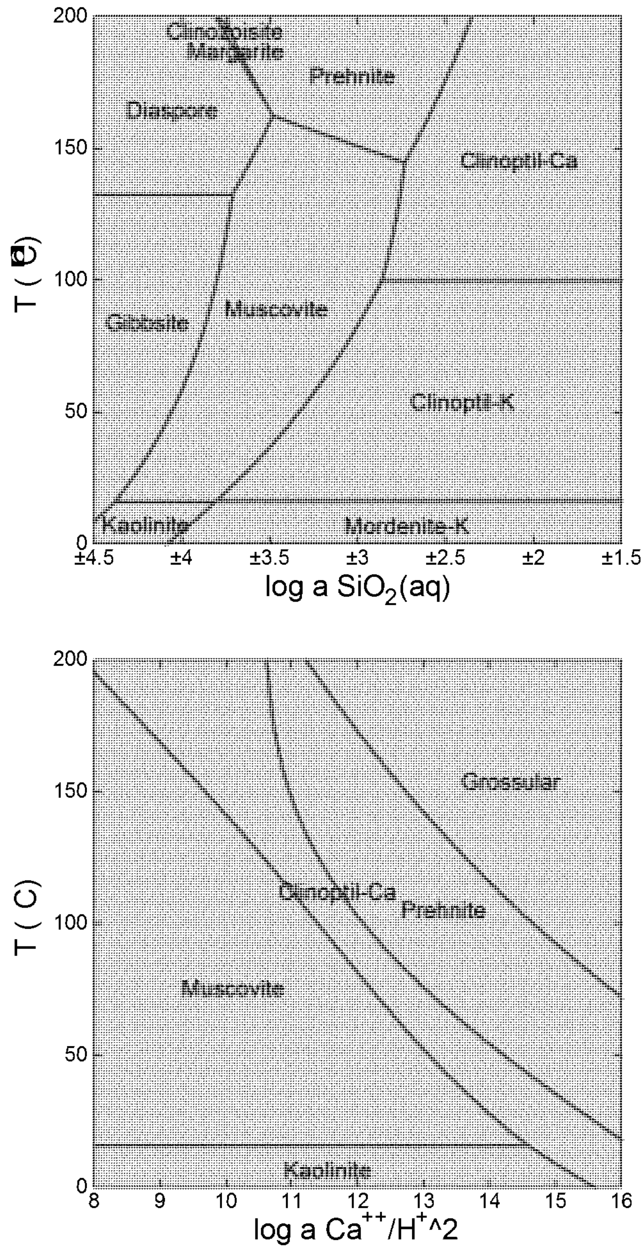


Figure 6.2 Stability of aluminosilicate minerals (a) versus $a_{SiO_2(aq)}$, assuming $a_{K^+}/a_{H^+} = 10^{3.5}$ and $a_{Ca^{++}}/a^2_{H^+} = 10^{10.5}$, and (b) versus $a_{Ca^{++}}/a^2_{H^+}$ at the same a_{K^+}/a_{H^+} ratio, assuming equilibrium with tridymite.

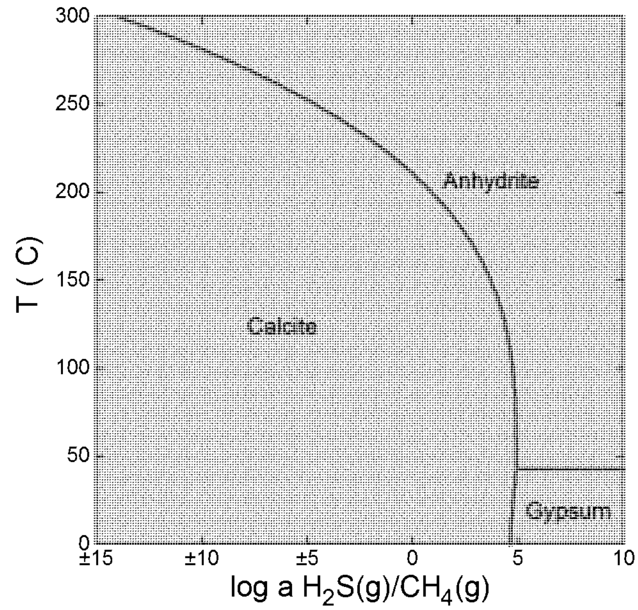


Figure 6.3 Equilibrium point of the methane souring reaction, calculated as a function of temperature.

```
diagram SiO2(aq) vs SiO2(aq)
x from -5 to -1
```

If you suppress quartz

```
(cont'd)
suppress Quartz
```

theresultingdiagram shows thesolubility ofthenextmosts tablepolymorph, tridymite (and asmall fieldfor chalcedony at high temperature). Continuing this cycleproduces plots of the solubilities of each of the silica polymorphs (Figure 6.4).

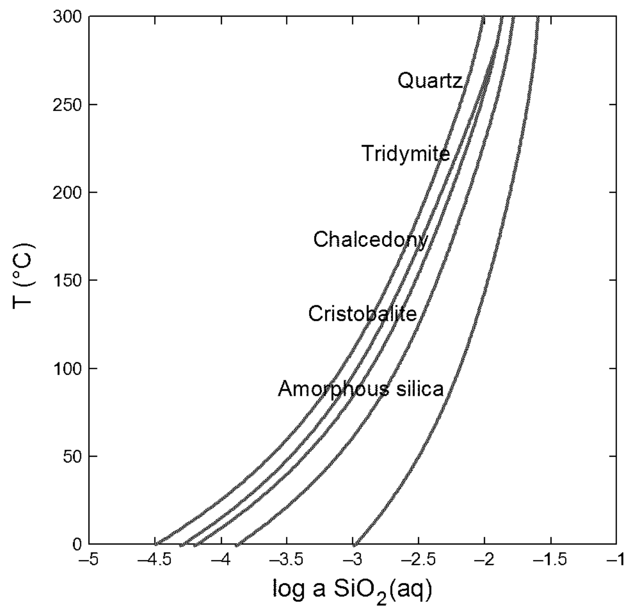


Figure 6.4 Calculated solubilities of silica polymorphs (shown as a composite of four Tact diagrams).

6.3 Mosaic diagrams

Tact, like Act2, can consider complexing ions that speciate over the diagram axes. To calculate the stable forms of uranium versus pH in the presence of dissolved phosphate, for example, Tact must first consider the speciation of the phosphate ion, which has already been calculated (see Figure 6.1). The steps

```
diagram U++++ vs pH
x from 0 to 14
log a U++++ = -10
log a HPO4-- = -3
speciate HPO4--
```

produce the diagram shown in Figure 6.5.

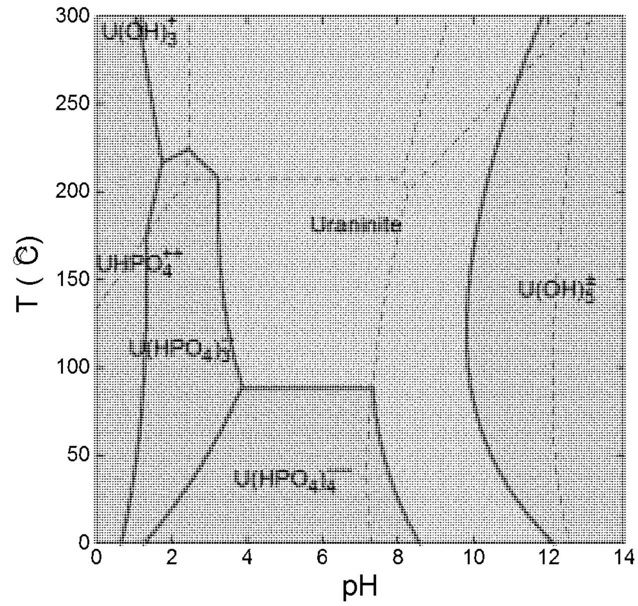


Figure 6.5 Mosaic diagram of the uranium-phosphate system versus temperature and pH. Broken lines show mosaic boundaries. Subdiagrams in mosaic, from upper left to lower right, are for $H_3P_2O_7$, $H_2P_2O_7$, H_2PO_4 , HPO_4 , and PO_4 .

6.4 Editing plot appearance

Tact, like Act2 allows you to interactively modify many aspects of the diagram. The details of using active items, aspect menus and dialogs to edit the plot appearance are given in the Using Act2 section of this guide.

6.5 Reaction traces and scatter plots

Tact, like Act2, can project reaction traces and scatter data onto a diagram. These features are especially useful for displaying polythermal reaction paths or datasets. The details of constructing such plots are given in the Using Act2 section of this guide.

6.6 Tact command line

You can start Tact by clicking the icon under the "Start" menu, opening a ".tac" file, or by entering the command "tact.exe" from the Windows "Command Prompt".

When you start Tact from the command line (as opposed to clicking on the icon), you can specify a number of arguments. For example, the command

```
tact -i my_script -d my_thermo.tdat
```

causes Tact to read input commands from a file "my_script", and to use "my_thermo.tdat" as the thermodynamic database.

The following options are available from the command line:

-cd	Change the working directory to the directory containing the input script specified with the -i option.
-d <thermo_data>	Set the file of thermodynamic data to be used.
-i <input_script>	Set a file from which to read input commands.
-pipe <pipe_name>	Set a pipe named pipe_name from which other programs can run Tact by remote control. Tact accepts input commands from the pipe, and writes output to it. If pipe_name is "stdio", the pipe is unnamed and uses the standard input and output data streams.

Using SpecE8

SpecE8 isaflexibleprogram thatmodels theequilibrium states of geochemical systems that contain an aqueous fluid. The program calculates the equilibrium distribution of aqueous species in a fluid, the fluid's saturation state with respect to minerals, the sorption of aqueous species onto various types of surfaces, and the fugacities of gases dissolved in the fluid.

7.1 Example calculation

The following steps equilibrate a hypothetical water sample at 25°C:

```
Na+         =  5   mg/kg
K+          =  1   mg/kg
Ca++        = 15   mg/kg
Mg++        =  3   mg/kg
Al+++       =  1   ug/kg
SiO2(aq)    =  3   mg/kg
Cl-         = 15   mg/kg
SO4--       = 35   mg/kg
HCO3-       = 50   mg/kg
pH          =  5
```

You do not need to type the unit, if it is the same as the unit on the previous line, although we will carry units throughout this manual for clarity. The following input is equivalent to that above:

```
Na+         =  5   mg/kg
K+          =  1
Ca++        = 15
Mg++        =  3
```

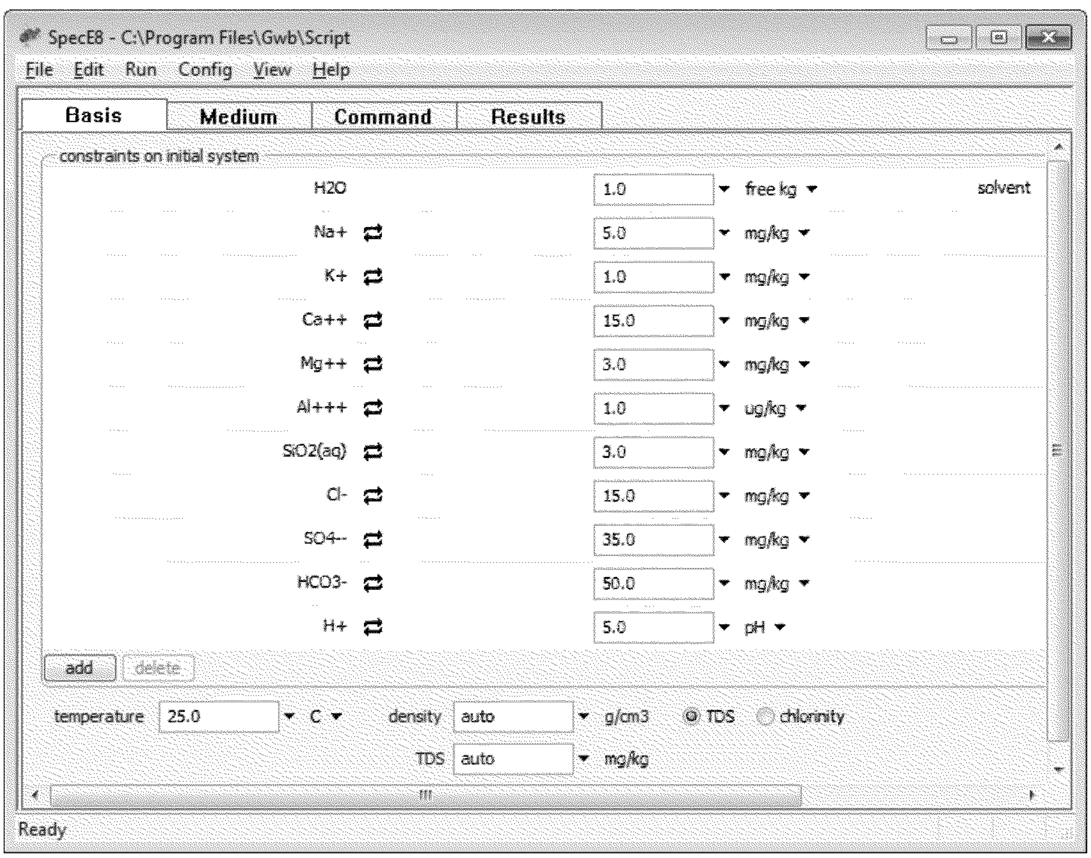
```
Al+++      = 1   ug/kg
SiO2(aq)   = 3   mg/kg
Cl-        = 15
SO4--      = 35
HCO3-      = 50
pH         = 5
```

You can further set concentrations in elemental equivalents: SO_4 as S, HCO_3 as C, $As(OH)_4$ as As, and so on. We could have in the lines above set

```
SO4--      = 12  mg/kg as S
```

to constrain the mass of sulfur, rather than that of the sulfate oxyanion.

Following the steps above, the Basis pane should look like



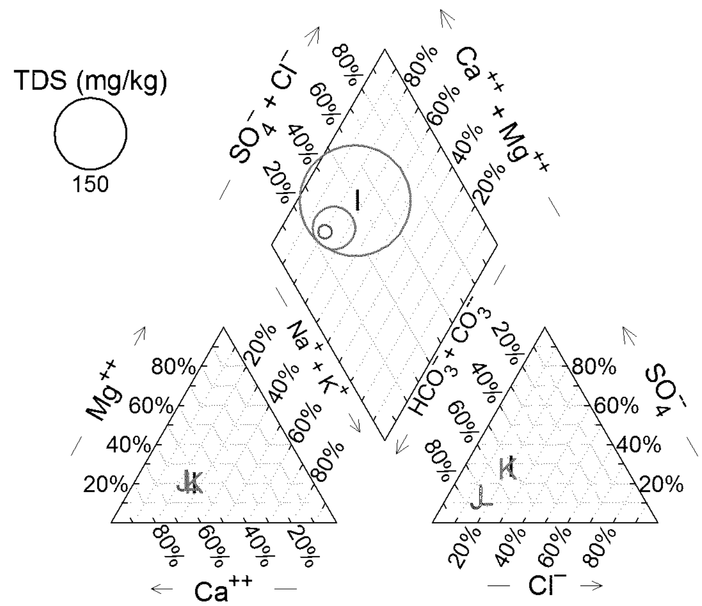


Figure 7.3 Piper diagram, as rendered by program Gtplot, showing the results of a SpecE8 calculation, with scatter data and TDS circles.

Press the Run button on the Results pane (or type “go” in the Command pane, or select Run ! Go from the menubar) to calculate the equilibrium species distribution in the fluid.

SpecE8 produces as output a dataset “SpecE8_output.txt” (click on View Results on the Results pane, or File ! View ! SpecE8_output.txt from the menubar) that shows calculation results in tabular form, and a dataset “SpecE8_plot.gtp” that passes more complete information to the graphics program Gtplot (see the section Using Gtplot in this guide). Figure 7.3 shows the results from the calculation above displayed on a Piper diagram, as plotted by Gtplot (from the SpecE8 menubar, select Run ! Gtplot).

7.2 Equilibrium models

When SpecE8 calculates a model of a system's equilibrium state, it uses the input constraints you provide to predict the distribution of dissolved species in solution, the fluid's saturation state with respect to various minerals, the amount of species sorbed onto any sorbing surfaces you specify, and the fugacities of gases dissolved in the fluid.

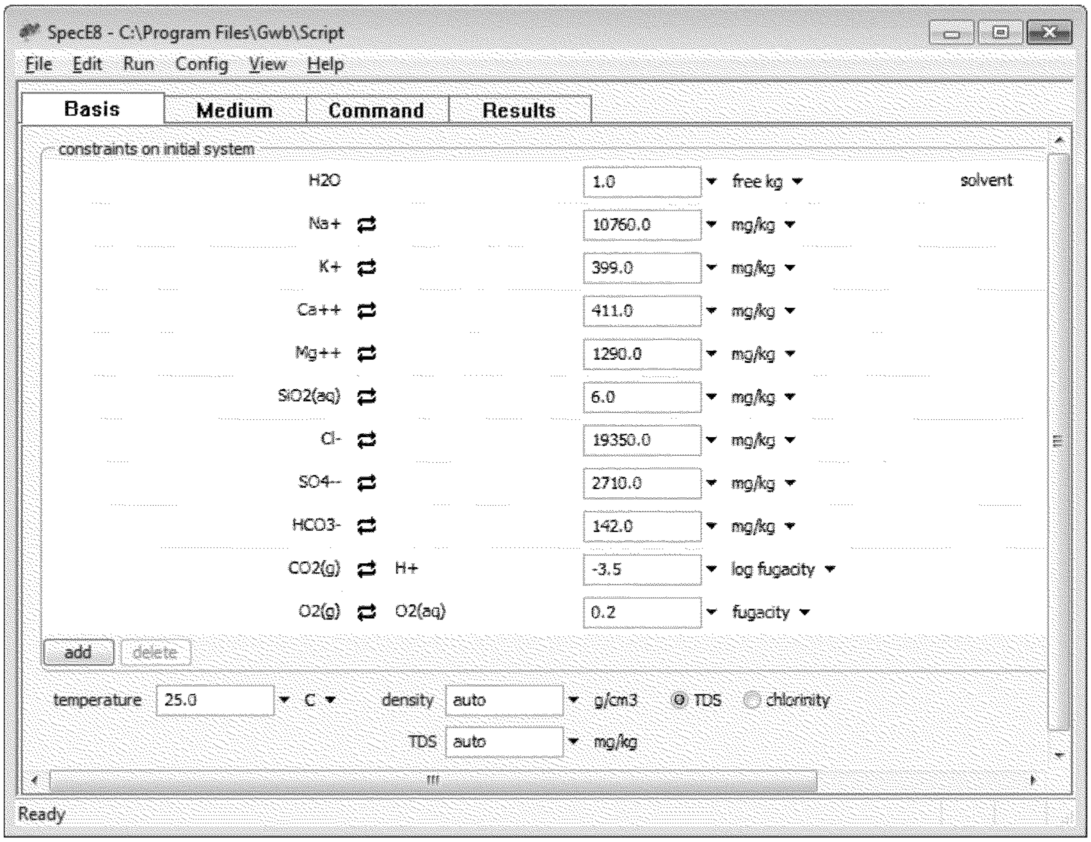
For example, to calculate the equilibrium state of seawater in contact with the atmosphere, you could assume that the seawater's oxidation state is controlled by the partial pressure of oxygen in the atmosphere and that pH is set by atmospheric carbon dioxide. To set the atmospheric buffer, you swap O_2 and CO_2 gases into the basis:

```
swap O2(g) for O2(aq)
swap CO2(g) for H+

Na+          = 10760    mg/kg
K+           =   399    mg/kg
Ca++         =   411    mg/kg
Mg++         =  1290    mg/kg
SiO2(aq)     =     6    mg/kg
Cl-          = 19350    mg/kg
SO4--        =  2710    mg/kg
HCO3-        =   142    mg/kg

f O2(g)      = 0.2
log f CO2(g) = -3.5
```

By default, the model calculation assumes that the system contains 1 kg of solvent water. Having followed the steps above, the Basis pane should look like



Execute the model by pressing the Run button on the Results pane, selecting Run ! Go from the menubar, or typing "go" in the Command pane.

When SpecE8 runs, it reports the imbalance in electrical charge in the system, as specifiedbytheinputconstraintsyouprovide. Alternatively, youcanhavetheprogram adjust the concentration of one component as necessary to achieve an exact ionic charge balance, and report the amount of adjustment. To do so, select "Balance on" under the unit pulldown menu for the desired basis entry. You could, for example, have the program adjust the Cl concentration. The analytical concentration entered above for Cl is a starting point for iterating to a solution in this case, not a true constraint on the system's composition.

When you run the preceding calculation, the "SpecE8_output.txt" dataset contains the calculation results for seawater, including the concentration of a number of aqueous species, the saturation states of various minerals, gas fugacities, and the system's bulk composition. You can compare the results to the input commands. The O_2 and CO_2 fugacities agree exactly. The concentrations of free species such as Na^C, however, do not agree with the input constraints. This apparent discrepancy occurs because the input sets the total amounts of all species containing Na^C, not just the Na^C ion. The fluid's bulk composition, toward the bottom of the block, reflects the input.

Tocalculateamodelinwhichthepresenceofamineralbuffer sthefluidcomposition, swap the mineral into the basis, and specify the mineral's mass, continue with the steps

```
(cont'd)
swap Quartz for SiO2(aq)
1 free cm3 Quartz
```

In this case, the system contains 1 kg solvent, various solutes, and 1 cm^3 of the mineral quartz. The amount of free quartz in the system does not affect the fluid composition, as long as some small amount of the mineral is present.

It is important to understand the difference between bulk and free constraints on the system's composition. In the previous example, the input constrains components Na^C, Mg^{CC}, and the others to a bulk number of mg/kg. The value for Na^C includes the sodium present in each of the dissolved species: Na^C, $NaSO_4$, NaCl, $NaHCO_3$, etc. Only by specifying units of free mg/kg would you constrain the Na^C ion alone. In contrast, pH is a free constraint, since it applies only to the free hydrogen ion, H^C. Settings for the O_2 and CO_2 fugacities similarly serve as free constraints.

You should set masses of minerals in the system as "free" constraints.

Thebulkamountofquartzinthesystem,bythesamereasoning , includes the mineral quartz plus the silica dissolved in solution as species such as SiO_2(aq). The commands in the example specify 1 cm^3 of free quartz (i.e., the silica present as the mineral quartz itself). Mineral buffers generally should be set as free constraints instead of bulk values.

When setting the concentration or activity of species, the mass of minerals, or the fugacity of gases in the Basis pane, it is important to avoid 0 (zero) values, as these will prevent the GWB programs from solving for the distribution of mass. Where the concentration of a particular component is negligible, set a small positive value. Log values, such as log activity, pH, pe, or Eh, however, can be set to zero.

SpecE8 recognizes a number of units for constraining a system's composition besidesthoseintroducedsofar.Mostofthesecanbeapplied eitherasbulkconstraints or as free constraints by preceding the unit name with the word "free". Table 7.1 lists the units recognized by the program.

By mass or volume (free or bulk):				
kg	g	mg	ug	ng
cm3	m3	km3	l	
By concentration (free or bulk):				
molal	mmolal	umolal	nmolal	
g/kg	mg/kg	ug/kg	ng/kg	
g/l	mg/l	ug/l	ng/l	
eq/l	meq/l	ueq/l	neq/l	
By carbonate alkalinity (applied to bicarbonate component):				
eq_acid/kg	meq_acid/kg	ueq_acid/kg	neq_acid/kg	
g/kg_as_CaCO3	mg/kg_as_CaCO3	ug/kg_as_CaCO3	ng/kg_as_CaCO3	
g/l_as_CaCO3	mg/l_as_CaCO3	ug/l_as_CaCO3	ng/l_as_CaCO3	
By activity or redox state (free constraints):				
pH	V	pe		
Relative to system bulk volume:				
By ionic charge balance (a bulk constraint):				

[1]Expressed per kg solvent.

7.3 Redox disequilibrium

Redox reactions in natural waters, especially at low temperatures, cannot always be assumed to approach thermodynamic equilibrium. For this reason, you may want to calculate a model in which redox reactions are in a state of disequilibrium. You control the extent to which SpecE8 honors redox equilibrium when calculating a chemical model by interactively enabling and disabling redox coupling reactions (see Redox couples in the Configuring the Programs chapter of this guide).

The coupling reactions, when enabled, prescribe redox equilibrium between species of differing oxidation states. You use the Config ! Redox Couples... dialog (or the "decouple" and "couple" commands) to control coupling between a redox species and a basis species. Table 2.2 shows the relationships among redox and basis species.

The example input

```
pH = 6
swap e- for O2(aq)
Eh = 0.400

0.4 mg/kg Ca++
0.6 mg/kg Mg++
0.1 mg/kg Na+
0.2 mg/kg K+
0.7 mg/kg Fe++
0.6 mg/kg HCO3-
3.0 mg/kg SO4--
1.4 mg/kg Cl-

decouple Fe+++
swap Hematite for Fe+++
1 free cm3 Hematite

decouple AsO4---
0.1 mg/kg AsO4---
0.8 mg/kg As(OH)4-
```

configures a model of a fluid of a certain pH, Eh, and major ion composition.

Disabling the redox couples between ferric and ferrous iron and between trivalent and pentavalent arsenic [i.e., basis species AsO_4 and $As(OH)_4$] causes the program to consider that oxidized and reduced iron and arsenic species exist in quantities not related to the value entered for Eh. Other redox couples, such as between HS and SO_4, remain enabled and will reflect the specified Eh.

By nature, you need more information to constrain a model of a fluid in redox disequilibrium than you do for an equilibrium model. In this example, separate constraints are required for the oxidized and reduced forms of iron and arsenic.

Analytical values constrain the fluid's total Fe^{CC}, AsO_4 , and $As(OH)_4$] content, and the amount of ferric iron in the fluid is controlled by equilibrium with hematite.

In the calculation results (in "SpecE8_output.txt"), SpecE8 honors mass balance andmassactionamongferricspeciesandamongferrousspeci es,butferricspeciesdo not exist inequilibrium withferrous species. Similarly, the program honors equilibrium among oxidized and reduced arsenic species, but not between oxidation states.

Whenever there are two or more independent redox couples in a run, SpecE8 reports in "SpecE8_output.txt" the theoretical oxidation state of each couple. In this example, the couples and corresponding Nernst Eh and pe values are:

	Eh (volts)	pe
e C 1=4 O_2.aq/ C H^C ½ H_2O	.400	6.762
2 e C 4 H^C C AsO_4 As.OH/$_4$	.081	1.362
e C Fe^{CCC} Fe^{CC}	.002	.035

The first line reflects the Eh specified as an input constraint. The second and third lines show the oxidation states calculated from the activities of arsenic and iron species. The differences in oxidation state reflect the extent of redox disequilibrium in the solution.

7.4 Activity coefficients

SpecE8 can employ one of two methods to calculate activity coefficients for the aqueousspecies.Mostcommonly,theprogramusesthe"B-dot "equation,anextended form of the Debye-Hückel equation described by Helgeson (see Further Reading). The method, which assigns a coefficient to each species in solution, is a general formulation that can be applied to a range of natural waters, including dilute fluids and dominantly Na-Cl solutions with ionic strengths of up to about 3 molal. The method is not especially accurate, however, at ionic strengths greater than about one-half molal.

In this method, species' activity coefficients are calculated by using the solution's ionic strength, and the water activity is calculated from the stoichiometric ionic strength. Because coefficients for themethod have been correlated toionic strengths of 3 molal, SpecE8 limits the ionic strength values it uses in calculating activities. For species activities, it uses the value of the actual ionic strength or the value of variable "timax", whichever is lowest. It calculates the water activity using the lower value of the stoichiometric ionic strength or variable "simax". Variables "timax" and "simax" are initially set to 3 molal, but you can change them (see Settable variables in this section) on the Config ! Iteration... dialog.

SpecE8 can emulate the activity coefficient calculations used in the MINTEQ, PHREEQC, and WATEQ4F software packages. These packages use Debye-Hückel based methods such as the Davies equation that are similar but not identical to the B-dot method described above. Consult the MINTEQ, PHREEQC, and WATEQ4F documentation for information about the ranges in temperature and ionic strength over which these calculations can be reliably applied.

Virial methods (the "Pitzer equations") provide an alternative technique for determining activity coefficients that can be applied to concentrated waters. The technique employs expressions similar to the Debye-Hückel equation, but with extra terms that represent interaction among the solution components. The virial coefficients that appear in the extra terms have been determined empirically by statistical regression of a body of experimental data.

SpecE8 makes use of a virial technique known as the Harvie-Møller-Weare (or H-M-W) method (see a reference by these authors in Further Reading). The H-M-W method may be used at very high ionic strength, but extra care should be taken because of the empirical nature of the virial techniques. Virial methods can give misleading results for fluids that differ in composition from those in the experiments used to regress the coefficients. Projecting the methods to elevated temperatures also requires caution because the model coefficients were derived largely from the results of experiments conducted at low temperature. In addition, the methods treat solutes in bulk without attempting to predict their distribution among the various aqueous species. Virial methods, nonetheless, commonly predict saturation states for concentrated solutions that are considerably more accurate than those calculated by the Debye-Hückel method.

Thevirial methods require their own databases, twoofwhich —"thermo_hmw.tdat" and "thermo_phrqpitz.tdat" — are included in the software release. Database "thermo_hmw.tdat" contains data from the Harvie-Møller-Weare compilation. This compilation contains data at only 25°C and should not be employed at any other temperature.

The "thermo_phrqpitz.tdat" dataset contains an expanded version of the H-M-W database,asimplementedinthePHRQPITZgeochemicalmodel (seeFurtherReading). The latter dataset includes more components than the H-M-W version and provides somecapability fortemperatureextrapolation. Thedatafo rtemperature extrapolation, however, is not complete; it is important to read the PHRQPITZ documentation carefully before working at temperatures other than 25°C. Table 7.2 lists the basis species available in each of the databases.

To use the H-M-W method, choose File ! Open ! Thermo Data... and select database "thermo_hmw.tdat", or enter the command

Harvie-Møller-Weare		
Ca++	HCO3-	Na+
PHRQPITZ		
B(OH)3	H+	Na+
Br-	K+	Sr++
Cl-	Mg++	

```
h-m-w
```

Similarly, selecting "thermo_phrqpitz.tdat" from this dialog, or typing

```
phrqpitz
```

invokes the PHRQPITZ database; the dataset "thermo.tdat", which you can invoke with the command

```
debye-huckel
```

returns the program to the default method for calculating activity coefficients.

In the following example, we use the Debye-Hückel and H-M-W methods to calculate the saturation index of halite in a groundwater sampled from an evaporite bed:

```
K+     =   7  g/l
Mg++   =  52  g/l
Na+    =  43  g/l
Ca++   =  .2  g/l
Cl-    = 205  g/l
SO4--  =  27  g/l
```

```
pH     = 7.2
go
```

This gives you the log Q=K of halite for the Debye-Hückel method. To compare with the Harvie-Møller-Weare method, type

```
h-m-w
go
```

The calculations give the results

	log Q=K
Debye-Hückel	0.94
Harvie-Møller-Weare	0.02

7.5 Sorption onto mineral surfaces

SpecE8 can model the sorption of species from solution onto mineral surfaces, accordingtoseveralmethods(see Sorption onto mineral surfaces inthe Configuring the Programs chapter of this guide). Toconsider sorption inyour SpecE8 calculation, you use the File ! Open ! Sorbing Surfaces... dialog (or the "surface_data" command) to point to a reaction dataset (or datasets) for the surface (or surfaces) of interest. To disable consideration of a surface complexation dataset, highlight the dataset on the Sorbing Surfaces dialog and touch the delete button, or type the command

```
surface_data remove <dataset>
```

To remove all surface datasets from consideration, select all of the datasets on the Sorbing Surfaces dialog and touch the delete button, or type the command

```
surface_data off
```

7.5.1 Surface complexation

Dataset "FeOH.sdat" describes sorption onto the surface of hydrous ferric hydroxide according to the two-layer surface complexation model. Adding this dataset, as described above, causes the program to consider surface complexation whenever a hydrous ferric hydroxide mineral such as $Fe(OH)_3$ precipitate, goethite, or hematite appears in the system.

As an example, the steps

```
surface_data FeOH.sdat

decouple Fe+++
swap Fe(OH)3(ppd) for Fe+++
1 free g Fe(OH)3(ppd)

pH =  5.3
 2.4    mg/kg Ca++
 3.5    mg/kg Mg++
  .04   mg/kg Ba++
  .4    mg/kg Na+
 1.2    mg/kg Zn++
15.     mg/kg SO4--
 8.     mg/kg Cl-
```

set up amodel of a dilute fluidcoexisting withaferric hydroxide surface. The program calculates the sorbing surface area from the amount of mineral present (1 g) and the specific surface area given in “FeOH.sdat” (600 m^2/g).

The compositional constraints apply tospecies in thefluid, excluding those sorbed onto the surface, unless you specify otherwise with the “sorbate” command (see SpecE8 Commands in the GWB Reference Manual). In the example above, the fluid contains 2.4 mg/kg Ca^{CC}, 15 mg/kg SO_4 , etc.; the mineral surface will be in equilibrium with the fluid and hence contain sites with additional amounts of calcium, sulfate, and so on.

SpecE8 writes the calculated sorbing surface area, surface charge density, mean surface potential, mole numbers of the surface species, and the sorbed fractions of eachcomponent into“SpecE8_output.txt”. Whenyoutracere action paths (see Using React in the GWB Reaction Modeling Guide), these variables are also available for plotting with Gtplot. In this example, Ca^{CC} and Ba^{CC} are sorbed only weakly, whereas Zn^{CC} and SO_4 sorb rather strongly.

Severaldatasets(“FeOH.sdat”,“FeOH+.sdat”,and“FeOH_m inteq.sdat”)describing surface complexation on hydrous ferric oxide are included in the software releases, but you can prepare additional datasets for other surface types. You can also invoke more than one dataset in a single SpecE8 calculation. For example, if you have prepared a dataset “SiOH.sdat” to describe sorption onto silica, adding both

```
surface_data FeOH.sdat
surface_data SiOH.sdat
```

causes SpecE8 to account for sorption onto both ferric and silica surfaces.

Theconstantcapacitance andconstantpotential modelsare variantsofthesurface complexationmodel.Yousetthesemodelsfromthe File ! Open ! SorbingSurfaces. . . dialog, or using the “surface_capacitance” and “surface_potential” commands (see Constant capacitance model and Constant potential model in the Configuring the Programs chapter of this guide).

7.5.2 Ion exchange

As described in the Configuring the Programs chapter of this guide (see the Ion exchange section), you can model ion exchange in two ways. The first method is to swap an activity ratio into the basis. This method is equivalent to assuming that there exists a sufficiently large reservoir of exchanging ions that the composition of the exchanging surface remains invariant.

Once you have swapped the activity ratio into the basis, you constrain its value. For example, the steps

```
swap Ca++/Na+^2 for Ca++
ratio Ca++/Na+^2 = 0.2
```

set the ratio $a_{\mathrm{Ca}cc}=a^2_{\mathrm{Na}c}$ to 0.2. To perform such a swap from the Basis pane, select ⇄ ! Ratio. . . .

For a more general treatment of ion exchange, you prepare a small dataset of the exchange reactions to be considered, using file “IonEx.sdat” as a template. You load the dataset of exchange reactions with the File ! Open ! Sorbing Surfaces. . . dialog, or the “surface_data” (or “read”) command

```
surface_data MyIonEx.sdat
```

You can load one or more exchange datasets (containing one or more exchange reactions) at a time, and in a single run combine ion exchange datasets with other types of surface reaction datasets.

SpecE8 in its calculations maintains a mass balance on the exchanging sites and reports the composition of the exchanging surface. You must therefore specify the exchange capacity in the modeled system on the File ! Open ! Sorbing Surfaces. . . dialog, or using the “exchange_capacity” command

```
exchange_capacity = 10 meq/g
```

Youcansettheexchangecapacity(i.e.,theCEC)intermsofe ither thetotalnumber of charge equivalents in the system (eq, meq, and so on), or the number of equivalents per gram of mineral (eq/g, ...). In the latter case, the program determines the total mineral mass in the system, including equilibrium, kinetic, and unreactive or inert minerals in the system, tocalculate the total exchange capacity. You set inert volume with the "inert" command, or on the Config ! Iteration... dialog); inert minerals are taken to have a density 2.65 g/cm^3.

The following steps provide an example of a SpecE8 calculation accounting for an ion exchange reaction:

```
surface_data IonEx.sdat
exchange_capacity = 100 meq

pH     =   6
Na+    =  20  mg/kg
Ca++  =  30  mg/kg
HCO3- = 250 mg/kg
SO4-- =  30  mg/kg
Cl-    =  15  mg/kg
balance on HCO3-
```

In this example, the amount of Na^{+} and Ca^{++} in solution controls the composition of the exchanging surface.

7.5.3 Distribution coefficients (K_d's)

To set up a calculation considering sorption described by K_d's, you read one or more datasets containing distribution coefficients for sorption reactions from the File ! Open ! Sorbing Surfaces... dialog, or using the "surface_data" command (see Distribution coefficients (K_d's) in the Configuring the Programs chapter of this guide). You prepare the datasets using as a template file "Kd.sdat", supplied with the GWB release.

Unlike the other sorption methods, this approach carries the sorbed concentration in moles per mass solid, rather than liquid phase. It is important in configuring a SpecE8 calculation, therefore, tospecify carefully themass ofmi nerals inthesystem. Minerals include equilibrium and kinetic minerals, as well as the unreactive or inert volume. You specify inert volume (in cm^3) with the "inert" command, or on the Config ! Iteration... dialog (the program converts this value to mass, assuming a density of 2.65 g/cm^3).

As an example of using the distribution coefficient method to model ion sorption in program SpecE8, consider the sorption of Pb^{++}

```
surface_data Kd.sdat
inert = 2000
```

```
pH     = 6
Na+    = 20 mg/kg
Ca++   = 30 mg/kg
SO4--  = 60 mg/kg
Cl-    = 40 mg/kg
Pb++   = 10 ug/kg
```

In this case, the program models a system including a fluid containing 10 μg/kg Pb^{++} in contact with minerals onto which a considerably greater mass of the ion is predicted to be sorbed.

7.5.4 Freundlich isotherms

To describe sorption in terms of Freundlich isotherms (see the Configuring the Programs chapter of thisguide), youprepare adataset ofsorption reactions following the format of file “Freundlich.sdat”. The procedure is otherwise parallel to use of the K_d approach, as described in the previous section.

Continuing the example above, the steps

```
(cont'd)
surface_data remove Kd.sdat
surface_data Freundlich.sdat
go
```

implement the Freundlich model in place of the K_d approach.

7.5.5 Langmuir isotherms

To model sorption according to Langmuir isotherms, you prepare a reaction dataset containing the sorbing reactions and their equilibrium constants, as described under Langmuir isotherms in the Configuring the Programs chapter of this guide. You prepare the dataset in the format of file “Langmuir.sdat”, which is distributed as a template with the GWB.

You enter the dataset into a SpecE8 run, as above. You can enter one or more Langmuir datasets, and mix Langmuir datasets with datasets for other sorption methods. As with the ion exchange method, you specify the total number of sorbing sites in either absolute terms (“mol”, “mmol”, ...) or per gram of dry sediment (“mol/g”, “mmol/g”, ...). You enter the sorption capacity on the File ! Open ! Sorbing Surfaces... dialog, or with the “exchange_capacity” command.

In the following example

```
surface_data = Langmuir.sdat

pH      = 8.3
Cl-     = 19000     mg/kg
Ca++  =    400      mg/kg
Sr++  =     10      mg/kg
Mg++  =   1300      mg/kg
Na+    = 10700      mg/kg
K+      =    400    mg/kg
SO4-- =   2700      mg/kg

exchange_cap = 10 mmol
```

program SpecE8 accounts for the sorption of Ca^{CC} and Sr^{CC} according to the Langmuir isotherms in the example dataset “Langmuir.sdat”.

7.6 Settable variables

SpecE8 allows you to alter the values of certain variables carried in the calculation. Table 7.3 liststhesevariables andtheir units anddefault values. Tochange avariable, type the new value in the Config ! Iteration... dialog box or on the Basis pane, or enter as a command the variable name followed by the new value. Examples:

```
itmax = 1000
epsilon = 10^-9
```

The value given must be in the units carried internally by the program, as listed in Table 7.3. To restore a variable to its default value, enter a blank field in the dialog box, or on the Command pane type its name without a value or followed by a “?”:

```
itmax
itmax = ?
```

Current values of the variables can be viewed at any time by looking at the dialog box or Basis pane, or using the command “show variables”.

7.7 Controlling the printout

SpecE8 lets you control the amount of detail presented in the calculation results written to “SpecE8_output.txt”. The dataset is known commonly as the “printout”,

density	not set	g/cm^3	Density of initial fluid.
inert	0	cm^3	Volume of inert minerals in system.
pitz_dgamma	0.1	–	For virial activity coefs., max. fractional change per iteration.
pitz_relax	0.5	–	For virial activity coefs., relaxation factor during iteration.
TDS	not set	mg/kg	Total dissolved solids, initial fluid.

although it need never be printed. The printout can contain information about (1) the concentrations and activities of dissolved species, (2) the saturation indices of various minerals, (3) gas fugacities, (4) surface complexes, and (5) the system's bulk composition in terms of elements of either the current or original basis. The printout can also contain a list of the chemical reactions considered in the calculation.

You can specify that any of these lists be excluded from the printout or included in a short or long format. To vary the printout, the user can set each aspect in Table 7.4 to "none", "short", or "long" on the Config ! Output... dialog, or in a command. For example,

```
print species = long
print saturations = none
```

The current print settings can be viewed at any time by looking at the three-way check boxes on the Config ! Output... dialog. A blank check box indicates exclusion from the printout, a check indicates inclusion in short format, and shading indicates inclusion in long format. Alternatively, type

```
show printout
```

print dataset	on	to "SpecE8_output.txt"
species	long	Aqueous species
saturations	long	Mineral saturation states
basis	none	Composition, current basis
elements	long	Elemental composition
stagnant	none	Composition of stagnant zone

7.8 SpecE8 command line

You can start SpecE8 by clicking the icon under the "Start" menu, opening a ".sp8" file, or entering the command "spece8.exe" from the Windows "Command Prompt."

When you start SpecE8 from the command line (as opposed to clicking on the icon), you can specify a number of arguments. For example, the command

```
spece8.exe -i my_script -d my_thermo.tdat
```

causes SpecE8 to read input commands from a file "my_script", and to use "my_thermo.tdat" as the thermodynamic database.

The following options are available from the command line:

-cd	Change the working directory to the directory containing the input script specified with the -i option.
-d <thermo_data>	Set the file of thermodynamic data to be used.
-i <input_script>	Set a file from which to read input commands.
-pipe <pipe_name>	Set a pipe named pipe_name from which other programs can run SpecE8 by remote control. SpecE8 accepts input commands from the pipe, and writes output to it. If pipe_name is "stdio", the pipe is unnamed and uses the standard input and output data streams.
-s <sorp_data>	Set the file of surface sorption reactions to be used.

Using Gtplot

Gtplot is an interactive, mouse-driven program that produces various types of diagrams showing the results of modeling aqueous speciation with SpecE8 or the data stored in a GSS spreadsheet.

Start Gtplot from SpecE8 by clicking on Plot Results on the Results pane, from GSS by selecting a graph type, or by opening a ".gtp" file.

After running SpecE8, start Gtplot by clicking on Plot Results onthe Results pane, or selecting Run ! Gtplot from SpecE8's menubar. The program will read the calculation results from the ".gtp" file SpecE8 produced and render them on any of a number of types of geochemical diagrams. You can leave Gtplot active when you run further SpecE8 calculations. Each time SpecE8 completes a run, it signals Gtplot,which updates its display to reflect the new results.

After preparing a GSS spreadsheet (".gss" file, see the Using GSS chapter of this guide), start Gtplot by selecting the analytes you want to plot and making a choice from the Graphs menu. The program will load the data values and render them initially on the chosen type of diagram. You can select which samples to plot in GSS by selecting the Graphs ! Selected Samples Only option and then choosing Graphs ! Update Graph(s). All open instances of Gtplot will be updated to reflect the new sample selection.

You can also start Gtplot by opening any ".gtp" file, clicking on the Gtplot icon under the "Start" menu, or by typing "gtplot -i filename" from the Windows command prompt.

You can take input from a different dataset by choosing File ! Open ! Data File... from the menubar and opening a ".gtp" or ".gss" file.

Gtplot opens awindow onyour computer screen, loads theinput data, andrenders the data as a two-dimensional plot. The window, as shown in Figure 8.1, has three parts: a graphics area, a menubar with pulldown menus, and a frame showing the name of the input dataset and its activity model.

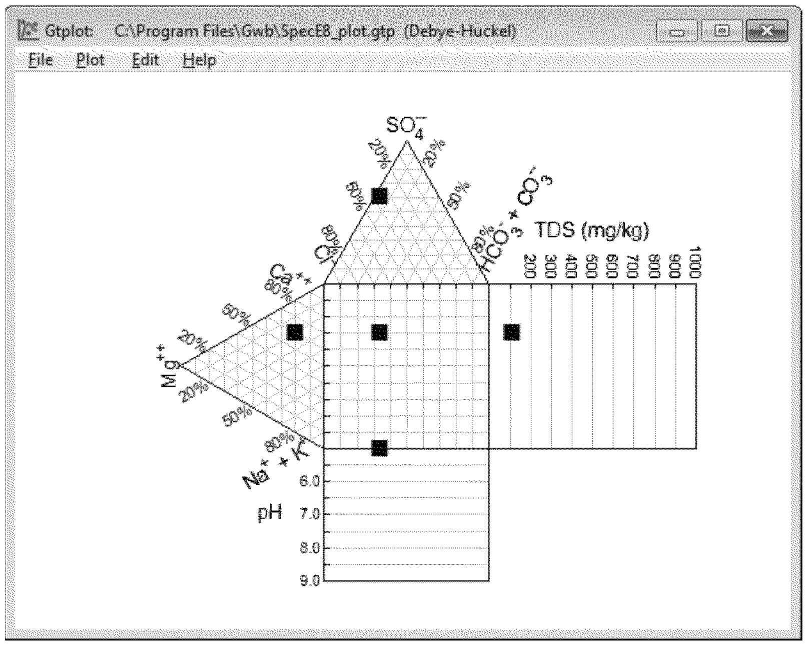


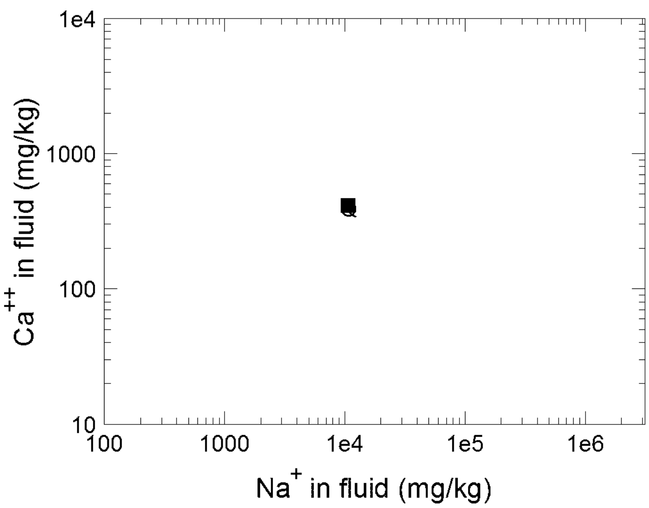
Figure 8.1 The Gtplot window.

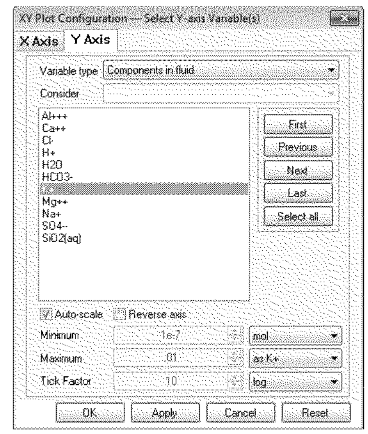
Gtplot worksusinginformation about thefluidmodeled, including itsbulk composition (i.e., its composition in terms of Na^{C}, Ca^{CC}, and so on), pH, TDS, and carbonate speciation. Plots labeled "HCO_3 + CO_3" show the sum of the concentrations in solution, in terms of electrical equivalents per kg fluid, of the free HCO_3 and CO_3 species. The program calculates this sum from the fluid's carbonate alkalinity, as determined bythe SpecE8 program. Hence, thevalueshownforthevariable depends not only on carbonate concentration, but the fluid's pH. In contrast, plots labeled "HCO_3" represent the bulk carbonate concentration of the fluid, taking no account of the speciation of carbonate to the CO_3 , HCO_3 , and CO_2(aq) species.

When Gtplot starts for the first time in a given directory, it assumes a default configuration. Upon finishing, the program saves for its next run a dataset containing the current configuration of your plots. You can select options from the File menu to specify an alternative configuration (see Loading and saving plot configuration) or reset the entire program configuration.

8.1 Plot types

Use the Plot menu to control the type and configuration of the plot produced.

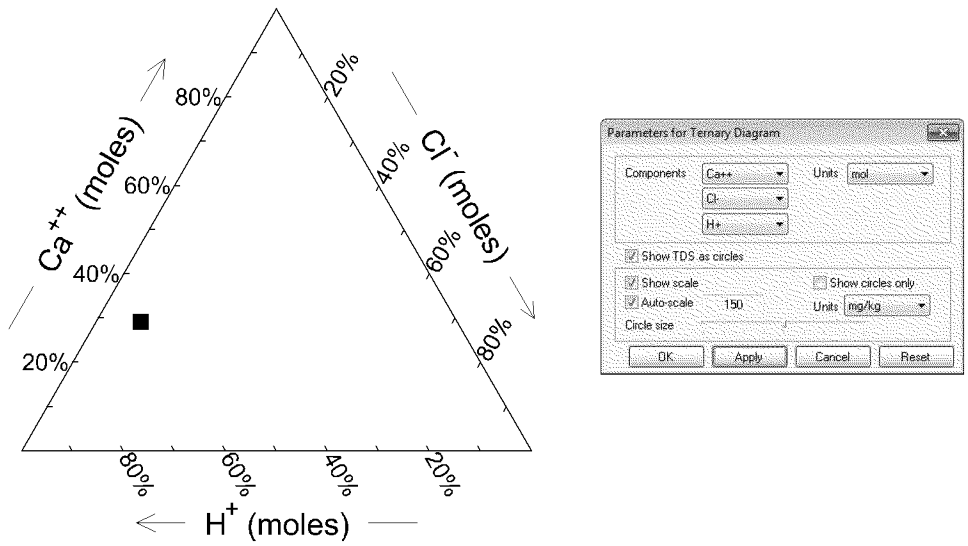




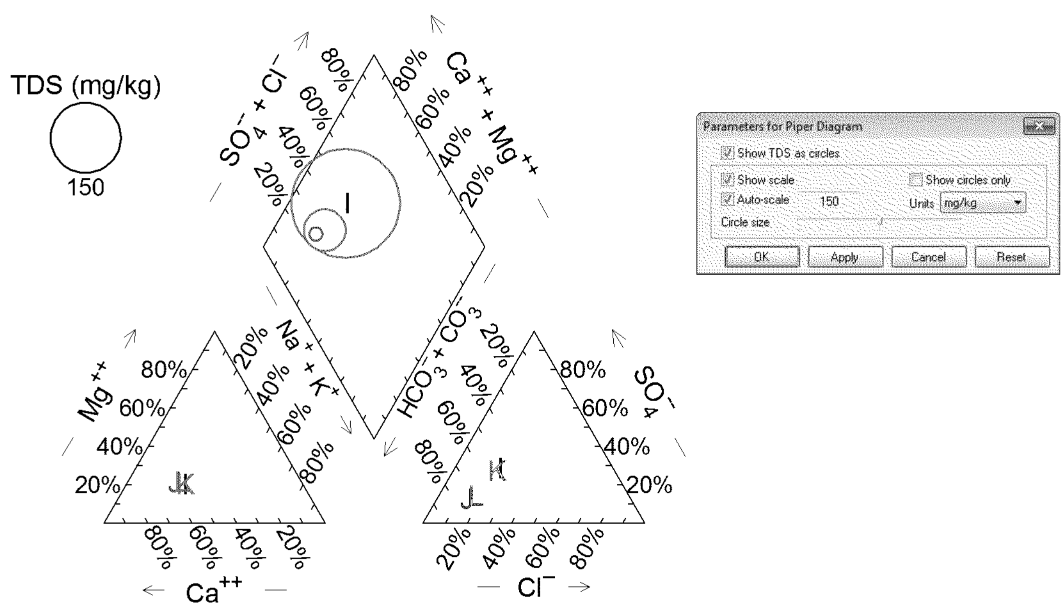
XY Plot shows a plot of fluid composition, with one component on the x axis and one or more components on the y axis. Use the following to specify the way the variables are plotted:

- Variable type to control the type of variables to appear along the plot's axes.
- Consider to list, for species or mineral saturation plots, the set of just those that contain a given basis species.
- Auto-scale to set the data range for the axis to span the data to be plotted.
- Minimum, Maximum, and Tick Factor to set the data range for the axis.
- Reverse axis to reverse the sense of the axis.
- Units to select alternative units, if any, for the axis.
- Type to set the axis to a linear, log, or delta scale. A delta scale shows change in a variable's value from the initial point in the reaction path.
- First, Previous, Next, and Last to cycle through the variable choices in the list box.

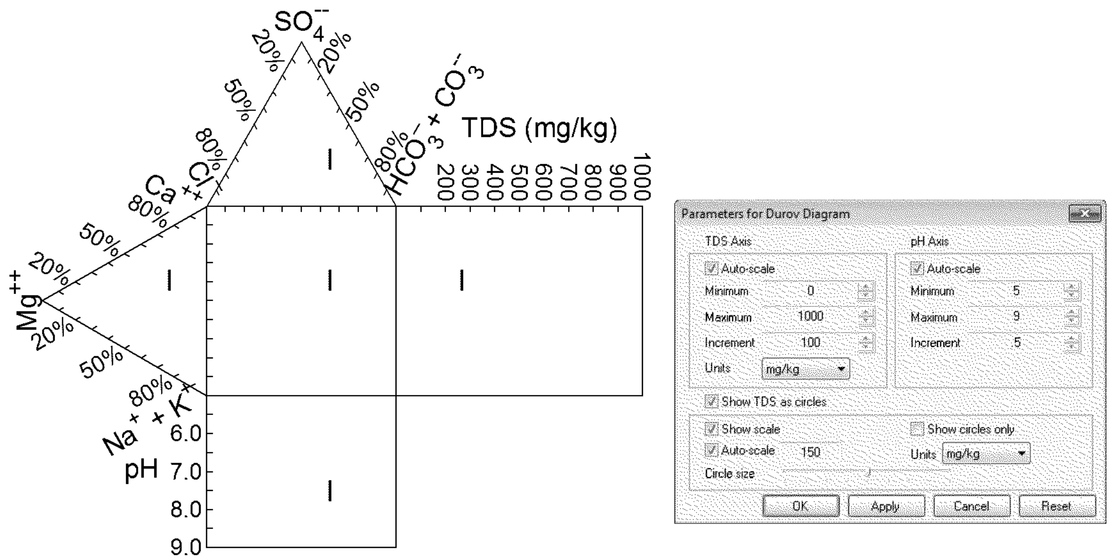
  Ctrl-click, Shift-click, and Select all for plots of more than one variable, to select multiple variables or a range of variables.



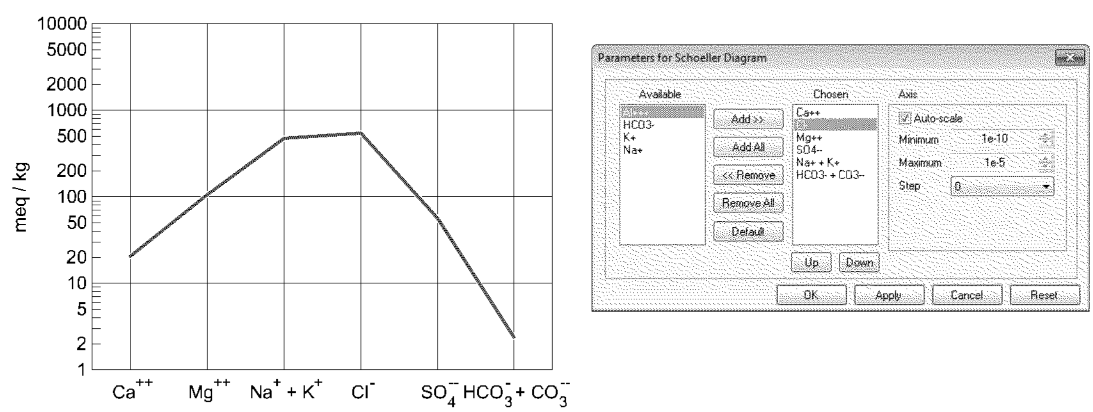
Ternary Diagram shows the fluid composition on a tri-linear plot.



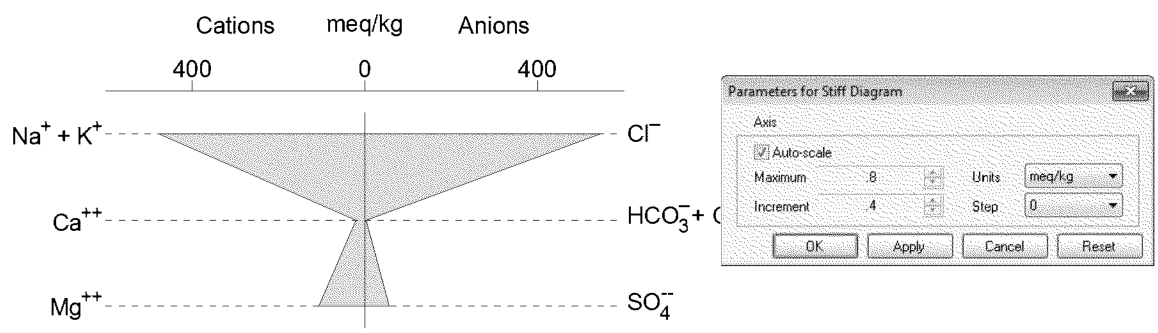
Piper Diagram shows the fluid's major ion composition.



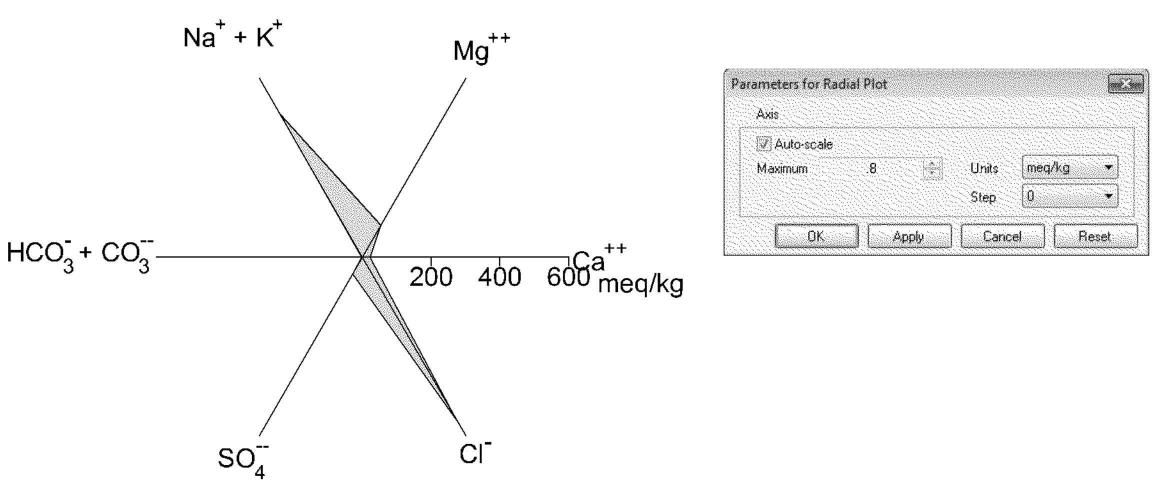
Durov Diagram represents the fluid's major ion composition, TDS, and pH.



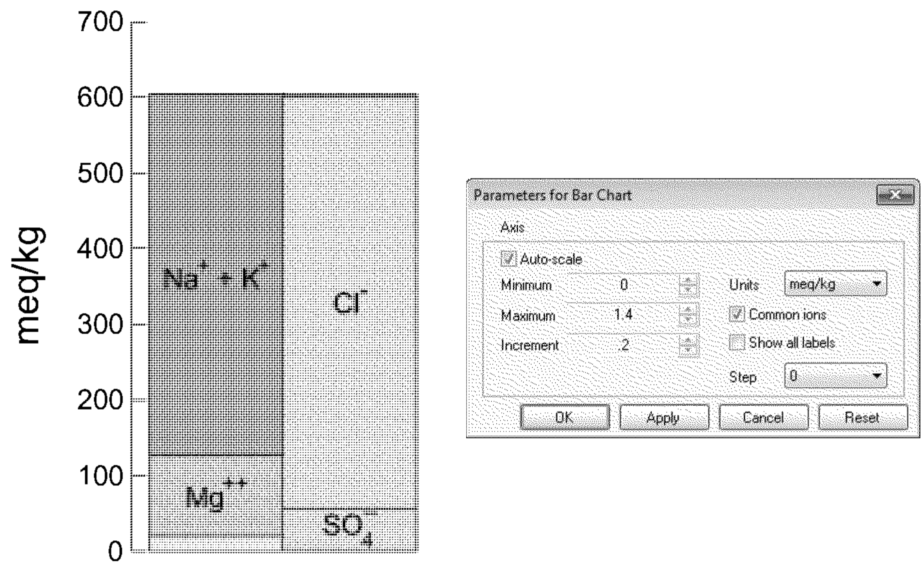
Schoeller Diagram shows the pattern of component concentration, on a logarithmic scale. You may choose the components to include in the diagram and arrange the order of components along the horizontal axis based on their order in the "Chosen" section of the configuration dialog.



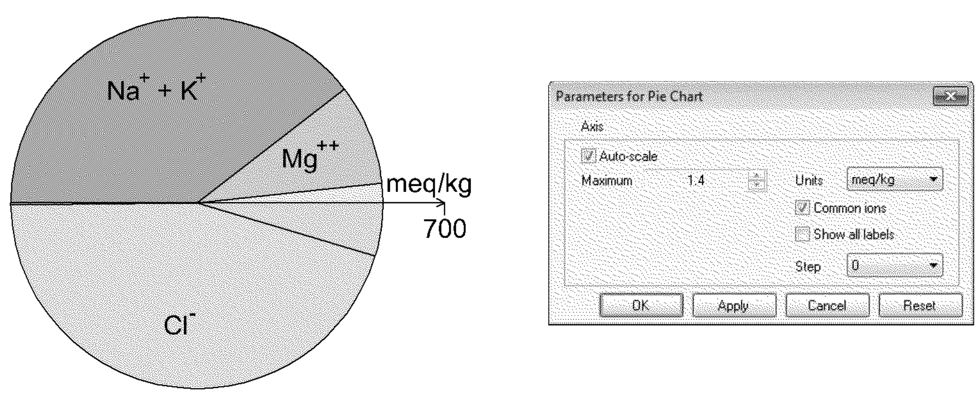
Stiff Diagram represents the fluid's major ion composition as a polygonal shape.



Radial Plot shows the fluid's composition in a manner similar to a Stiff diagram, but in radial coordinates.



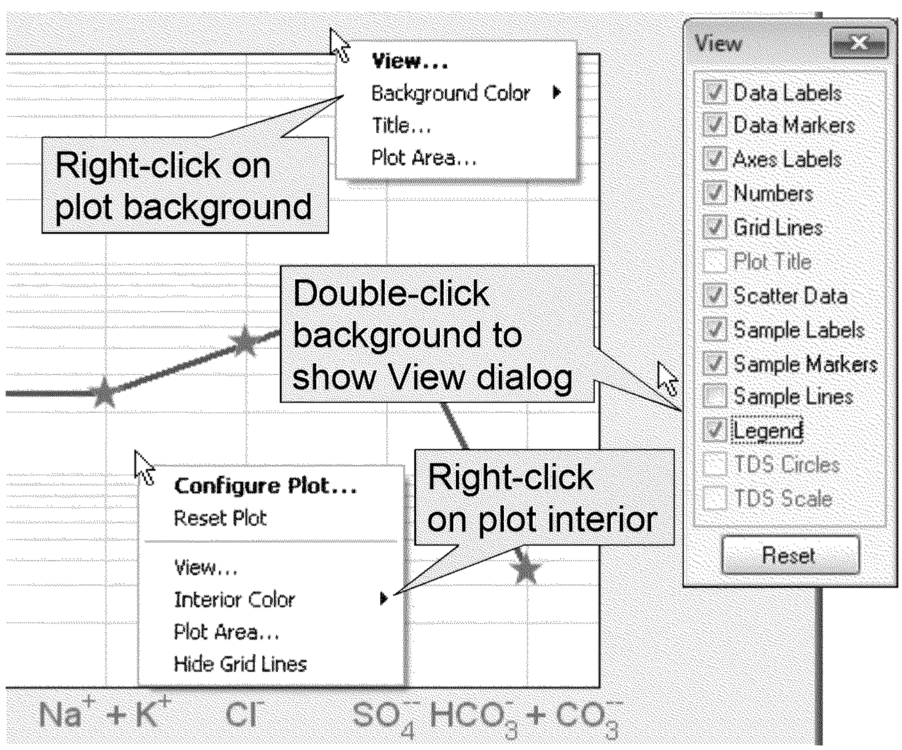
Bar Chart represents the fluid's cation-anion balance graphically.

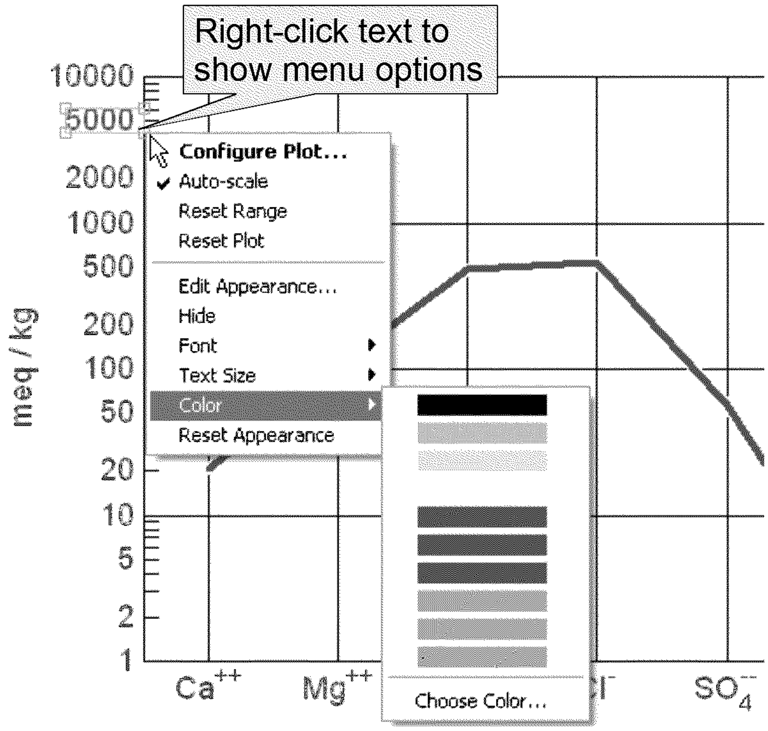


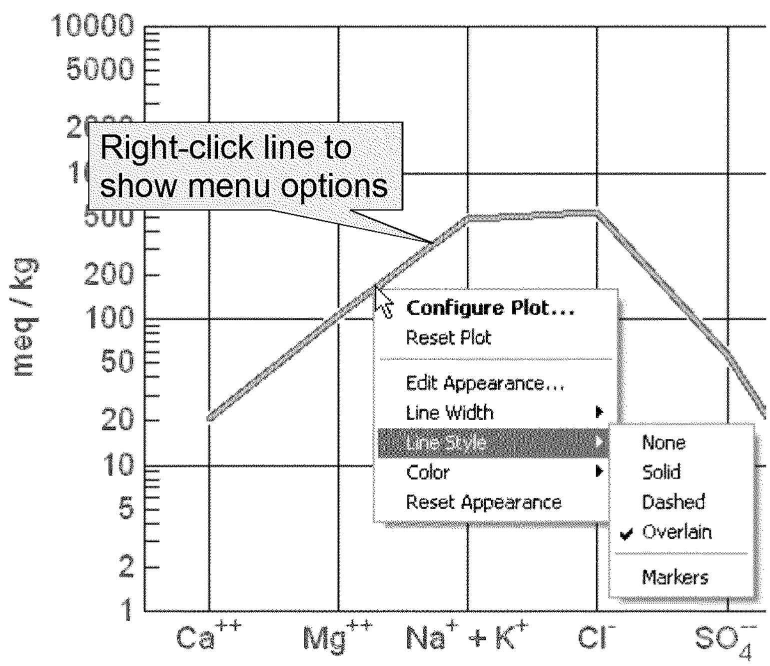
Pie Chart is an alternative method for showing cation-anion balance, with the radial direction representing the fluid's total electrical equivalent content.

8.2 Editing plot appearance

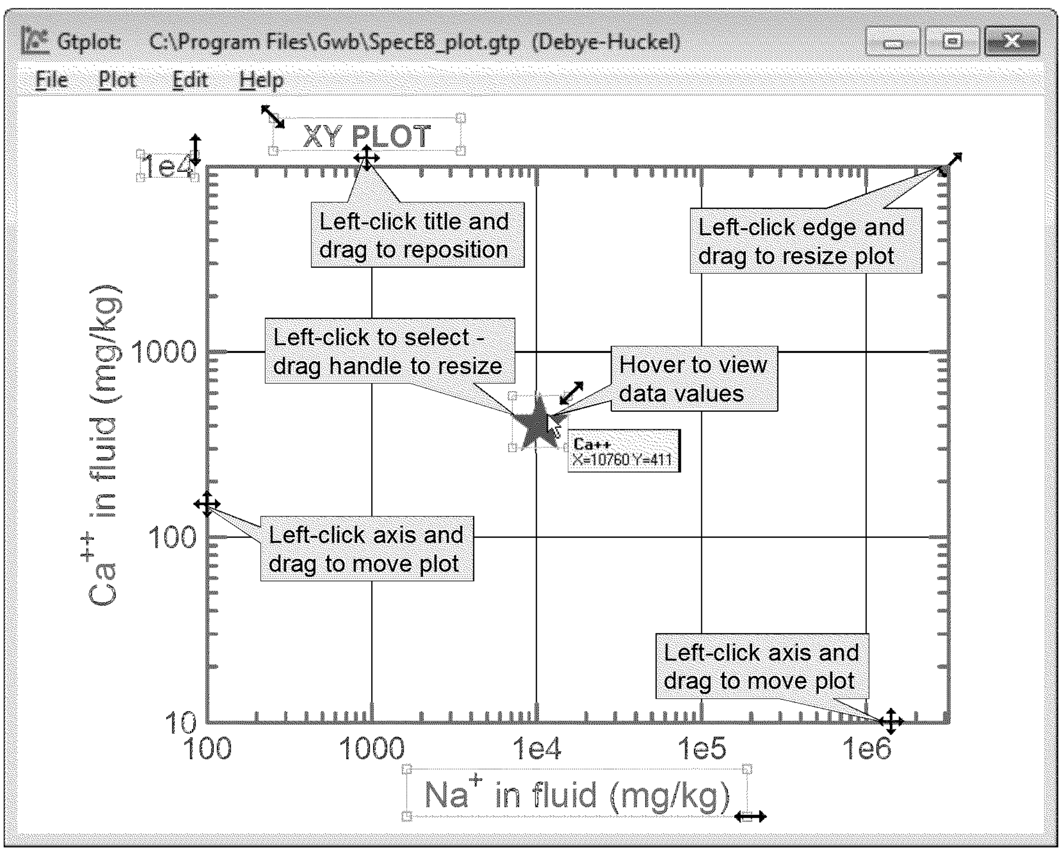
In Gtplot you can interactively modify many aspects of the diagram. A right-click on an aspect or area of the plot displays a menu showing the options available. You may choose to reset an axis range or an aspect's appearance to its default state. Using Edit ! Font will change the font for the entire plot. To change the font for individual aspects, choose Font from that aspect's menu. A double-click on an aspect brings up a dialog box related to the first item on the pulldown menu, which in most cases is the plot configuration dialog. These dialogs can also be accessed through the Plot menu. The aspect appearance dialogs can be accessed through the Edit menu. A double-click on the background area will bring up the View... dialog, which lets you select the graphical elements to be shown.

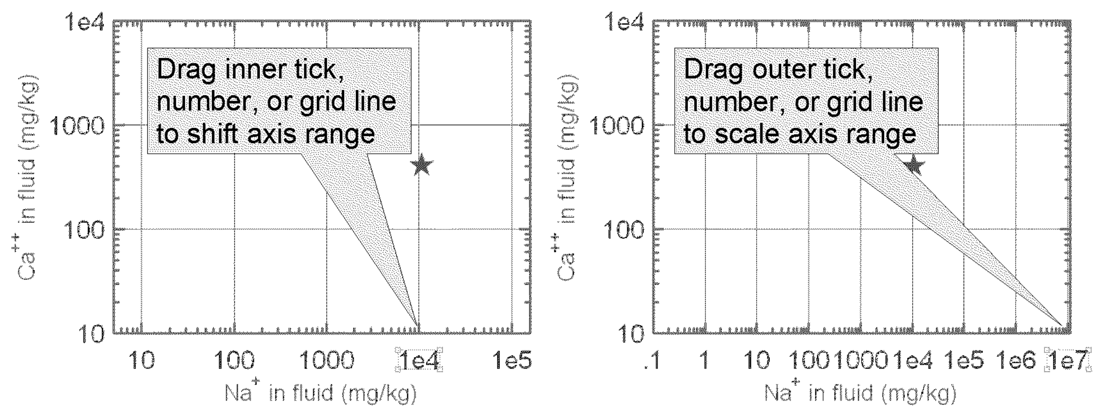



Right-click text to show menu options
10000
5000
2000
1000
500
200
100
50
20
10
5
2
1
meq / kg
Configure Plot...
Auto-scale
Reset Range
Reset Plot
Edit Appearance...
Hide
Font
Text Size
Color
Reset Appearance
Choose Color...
Ca++
Mg++
Cl-
SO4--


10000
5000
Right-click line to show menu options
200
100
50
20
10
5
2
1
meq / kg
Configure Plot...
Reset Plot
Edit Appearance...
Line Width
Line Style
Color
Reset Appearance
None
Solid
Dashed
Overlain
Markers
Ca++
Mg++
Na+ + K+
Cl-
SO4--

A left-click on an aspect causes it to be "selected". An aspect has been selected whenitscolorchanges,asinthecaseoflines,orwhenitissu rroundedbymanipulation handles, in the case of text or markers. Change the size of text, markers, and, in the case of the XY Plot, the plot itself by dragging the sizing cursors. Adjust the placement of the plot by clicking within the plot or on either axis and dragging it. The plot title can be moved in the same way.



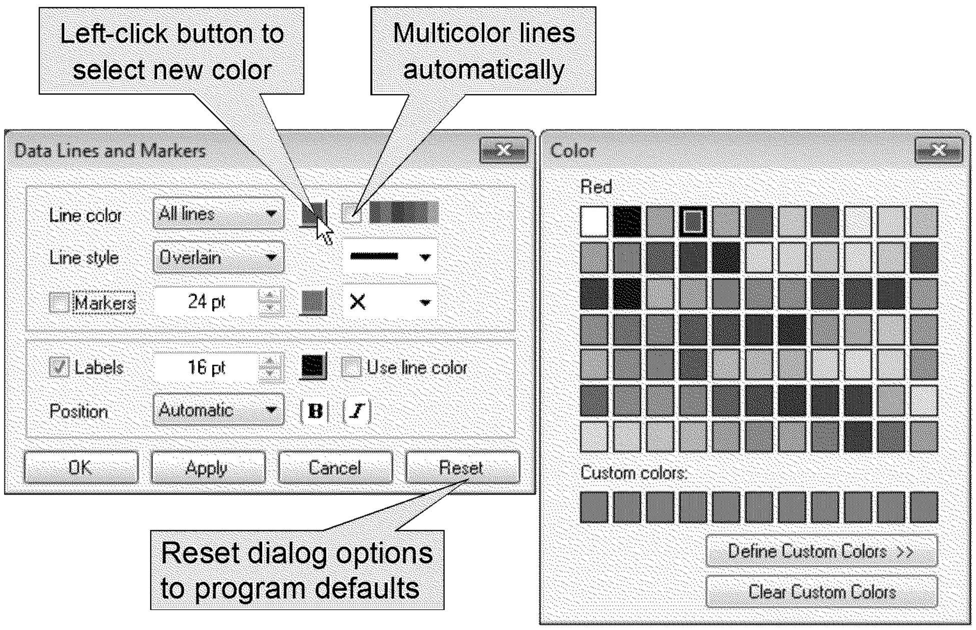


When you read new input data and update the plot with the Auto-scale option set, Gtplot automatically adjusts the axis ranges to the new data. Otherwise, Gtplot maintains the axis ranges you have set for the previous plot. This option lets you quickly adapt the axis ranges to new data.

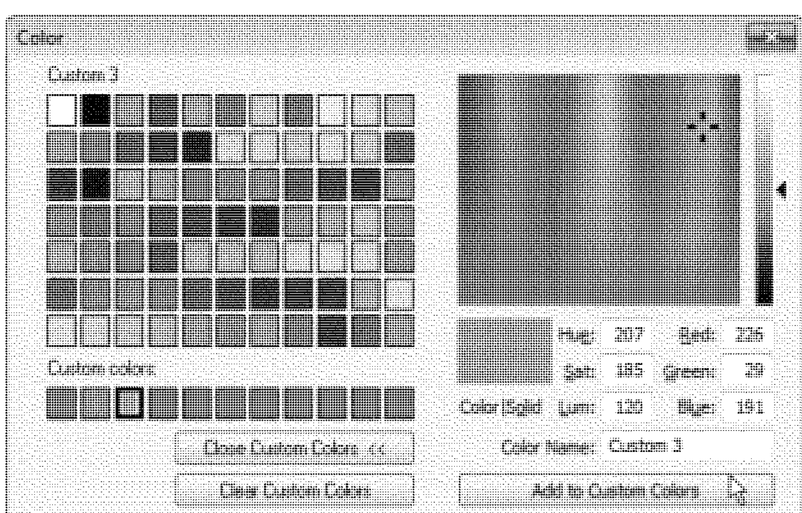
You can change the range on an axis by clicking and dragging a tick mark, number, or grid line. Dragging a tick within an axis shifts all of the values along the axis, effectively changing the minimum and maximum values at the ends of the axis, but keeping the spacing the same. Dragging the tick at an end of an axis changes the minimum or maximum value. Any tick in a Stiff diagram, radial plot, or pie chart behaves like an end tick because the minimum is always zero and cannot be changed. To reset the axis range to span the range of the data being plotted, choose Auto-scale or Reset Range from the aspect menu, or Plot ! Reset Axis Range.

Youcansetallofthegraphicalattributesintheaspectappe arance dialogs available through the Edit menu. When you make changes tovalues or selections inan aspect appearance dialog, the changes don’t take effect on the plot immediately. You may set up your choices for as many of the aspects as you like, or use the “Reset” button to reset the dialog to its default values. Use the “Apply” or “OK” button to apply the changes to the plot. Use the “Cancel” button if you decide that you don’t want the changes applied.

Selecting Color ! Choose Color... from any aspect menu or clicking on any color button in an aspect appearance dialog will allow you to set the color of the relevant aspect. The Color dialog initially presents a selection of named colors to choose from, with the current color of the aspect highlighted.



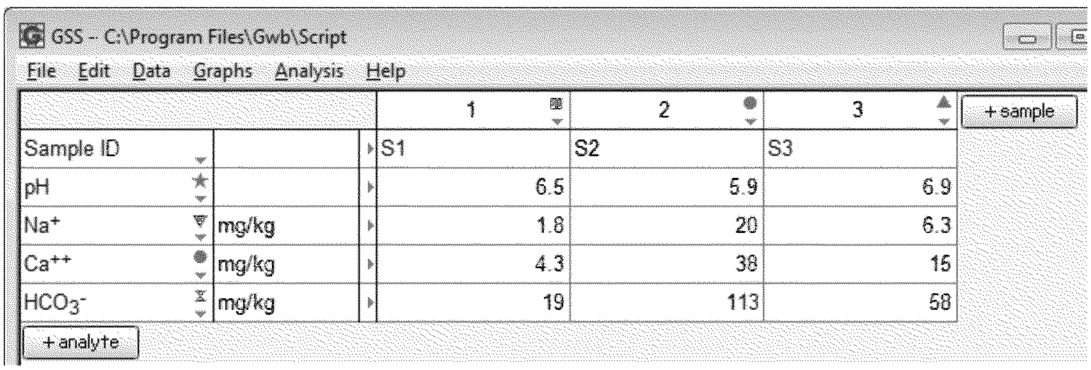
You may create custom colors. To do so, in the Color dialog double-click any of the named colors or click on "Define Custom Colors". This displays the extended version of the dialog through which you can create a custom color. Once you are satisfied with the color you have created, you may give it an optional color name, then choose "Add to Custom Colors". The color is then available to be chosen just like any of the other named colors.



8.3 Scatter data

Gtplot can plot the data in a GSS data sheet (a .gss file) as “scatter data” in its own diagram, or overlain onadiagram oftheresults of a SpecE8 or React calculation. You can plot system parameters in your data sheet, like pH and TDS, or the measured composition (mg/kg Na^{C}, ...) of the samples in the sheet. Or you can plot “calculated analytes” such as species activity, gas fugacity, and mineral saturation state.

Your .gss file might look like



To read the file into Gtplot, select File ! Open ! Scatter Data. . . . If some of the data points lie outside the plot’s axis range, touch Ctrl+Z. Clear scatter data from a diagram on the Open ! Scatter Data. . . dialog, with the OFF button.

The marker representing each sample in the scatter data is set in the .gss file. In GSS, right-click on a sample to change the marker used, and its color and size. When you modify a .gss file, you must save it and in Gtplot reload it, using the Open ! Scatter Data. . . dialog, to see the changes.

On x-y plots, you can associate the marker for a data point with the analyte (Na^{C}, Ca^{CC}, ...), rather than the sample (Well #1, Well #2, ...). On the Edit ! GSS Data. . . dialog, you can assign the marker, its color, and its size according to the settings in the .gss file for the analytes, or for the samples.

You can label each scatter data point with the sample’s “Sample ID”, as set in the .gss file, and display a legend showing the symbols used. In Gtplot, choose Edit ! GSS Data. . . and under “Labels” select the checkbox for “Sample” to show sample labels, and the “Legend” box to display the legend. If the “Color from sample” box is checked, the color for each sample label matches that of the sample’s marker. Use the Edit ! View. . . dialog to quickly toggle on and off display of the scatter data, data labels, and legend.

If an analysis falls below detection limit, enter in your GSS data sheet the detection limit preceded by a “<”, for example “< 0.01”. Gtplot will add a downward arrow to the symbol for this entry, signifying it represents the upper limit to concentration. To add error bars to the scatter points, enter triplets, like 0.5|2.0|3.5, in the data cells in your .gss file (see Error bars in Using GSS).

In plots showing the variable "$HCO_3 + CO_3$", you should enter a value in the scatter dataset for the system parameter "Carbonate alkalinity", so Gtplot can render the variable correctly. If you do not enter a value for alkalinity, the program will render the variable in terms of the reported HCO_3 concentration, if available, in which case the diagram produced will not account for the speciation of carbonate.

Certain unit conversions, such as changing mg/l to mmolar, or mg/kg of solute to mg, require knowledge of the fluid's density and TDS, and the mass of solution in the system. Gtplot first looks for entries "Density", "TDS", and "Mass solution" in the .gss file. If it does not find them, it estimates density and TDS, and assumes a solution mass of 1 kg.

In order to see TDS represented as circles on Piper, ternary, and Durov diagrams, you should enter a value for dissolved solids for each sample.

To coordinate the plotting of scatter data versus time on a reaction path, include values for "Time elapsed", "Time", and/or "Date".

In GWB releases 7.0 and earlier, the program took scatter data from a specially formatted text file, rather than a .gss datasheet. Legacy scatter files are still supported and described in the Scatter Data appendix in the Reference Manual.

8.4 Loading and saving plot configuration

Gtplot writes into the user's working directory a file, "gtplot_conf.gtc", containing the configuration of the current plots. When the program starts again in the same directory, it reads the file and assumes the same configurations.

Choosing File ! Reset Configuration or the "-reset" option from the command line (see Gtplot command line) returns the configuration for each plot type to its default state. This option is useful, for example, when you begin to examine results of a SpecE8 simulation unrelated to the previous run.

You can save plot settings to an alternative configuration file by selecting File ! Save As.... Later, double-click on the ".gtc" file to re-open the plot you saved. You may also read the file into Gtplot by selecting File ! Open ! Configuration..., or simply dragging it into an instance of Gtplot.

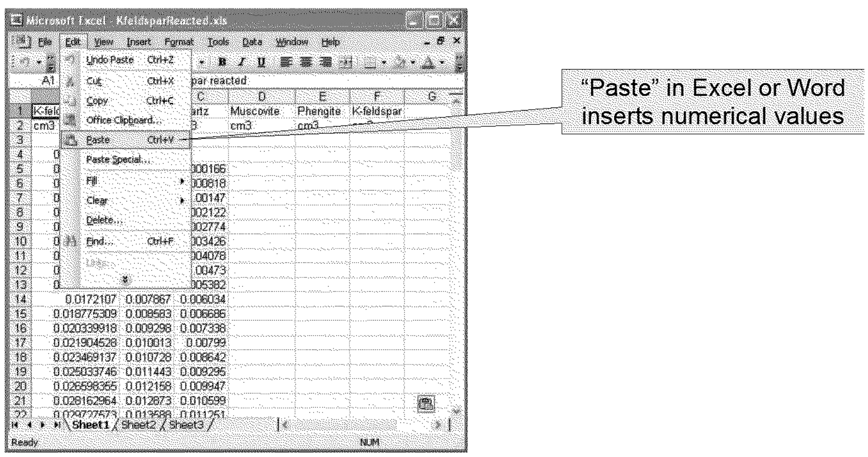
Exiting the program by choosing File ! Abort (No Save) causes an immediate exit from the program; the plot configuration is lost.

8.5 Exporting the plot

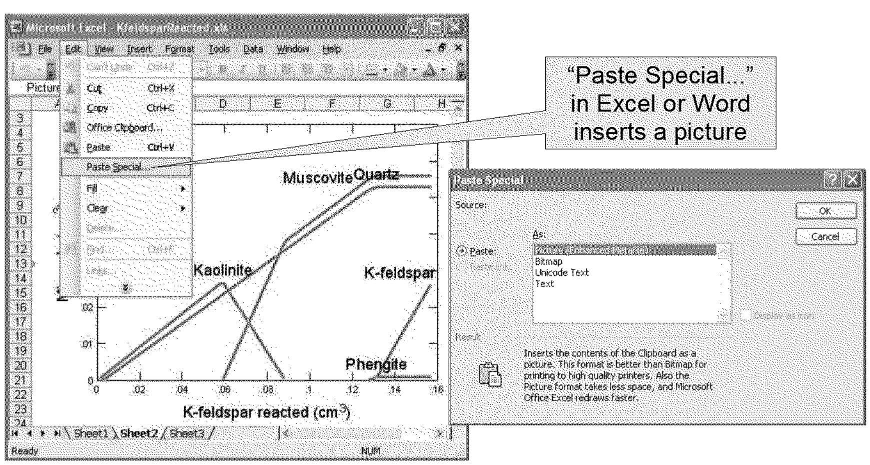
Gtplot makesitconvenienttousetheplotsyoucreateinarticles,r eports,presentations, and databases. You can copy the current plot to the clipboard and then paste it into a variety of applications, in a format meaningful to the application.

Tocopyaplot,use Edit ! Copy or Ctrl+C. IfyoupastetheplotintoMSPowerPoint, it will appear as an EMF (an MS Enhanced Metafile) graphic object. Pasting into Adobe Illustrator places a native AI graphic.

If you paste the plot into MS Excel or a text editor such as Notepad or MS Word, the numerical values of the data points that make up the lines on the plot will appear in spreadsheet format.



In MS Word or MS Excel, use Paste Special. . . to paste the plot as a picture instead.



You can control the format in which the plot is copied to the clipboard by selecting Edit ! Copy As. You can choose to copy the plot as an AI object, an EMF object, a bitmap, or the data points in the plot, as tab delimited or space delimited text. Use the tab delimited option to paste the data into a spreadsheet program like MS Excel. For examining the data in a text file created with an editor like Notepad or MS Word, the space delimited option writes a nicely aligned table.

Use File ! Save Image... to copy the plot, in your choice of formats (selected under Save as type:), from the graphics area to a file in the specified directory. The Enhanced Metafile option, for example, saves the plot image in a format that can be read by most art and illustration programs (see Graphics Output in the GWB Reference Manual). The other file formats available are: Encapsulated PostScript, Color PostScript, B/W PostScript, Adobe Illustrator, Scalable Vector Graphics, Compressed SVG, PDF, and Bitmap. When saving a bitmap file, you may specify the quality of the saved image by choosing its resolution: High, Medium, Low, or Custom. Use the Custom... dialog to set the pixel width and height of the image, and to choose whether to preserve the aspect ratio of the plot. Use the Spreadsheet File (Tab delimited) or Text File (Space delimited) option to save into a table the numerical coordinates of the data points on the plot. The spreadsheet table may be read directly into many popular spreadsheet programs.

Certain graphics types support font embedding. PDF files should always display and print properly, regardless of fonts installed on the system. PostScript files should also, if you have used the option to embed fonts. If you may want to edit the PostScript file, however, you should deselect the option to embed fonts, because programs such as Adobe Illustrator may restrict your ability to edit a document using embedded fonts. To edit these files, be sure that all of the required fonts are installed on your computer (see Font for data markers in the GWB Reference Manual).

When importing AI graphics to Adobe Illustrator, the program may prompt you to update the legacy text before you can edit the file. In this case, choose "Update". You need to release the clipping mask before you attempt to edit individual elements of the plot. Use the "Ungroup" and "Group" functions when repositioning or modifying elements.

8.6 Gtplot command line

To run Gtplot, click on the Gtplot icon under the “Start” menu, or open a “.gtp” file. The program can also be initiated from within an MS DOS window by typing “gtplot.exe” at the command prompt. Starting the program in this way allows you to make use of the command line arguments described below.

Gtplot accepts a number of arguments from the command line. For example, the command

```
gtplot -i SpecE8_plot1.gtp -c Config1.gtc
```

causes Gtplot to read as input the file “SpecE8_plot.gtp”, and to use the plot configuration stored in “Config1.gtc”.

The following options are available from the command line:

-i <input_data>	Set the "SpecE8_plot.gtp" dataset, produced by a SpecE8 run, which contains the data to be plotted. The program, by default, looks for file SpecE8_plot.gtpin the user's working directory.
-c <config_file>	Set the configuration file to be read at startup. By default, the program reads the file gtplot_conf.gtcif it exists in the working directory.
-scat <scatter_file>	Take scatter data from the named dataset. By default, Gtplot does not plot scatter data.
-reset	Set the default configuration at startup; do not read gtplot_conf.gtc
-graph <plot_type>	Set the type of plot displayed at startup. By default, it is set from the configuration file. Choose from: xyplot, ternary, piper, durov, schoeller, stiff, radial, bar, pie, series, and time.

Ctrl+Shift+A	Copy plot to the clipboard in Adobe Illustrator format
Ctrl+C	Copy plot to the clipboard
Ctrl+F	Refresh the display
Ctrl+L	Load a configuration file
Ctrl+O	Open an input (“SpecE8_plot.gtp”) file
Ctrl+Q	Quit Gtplot, save configuration
Ctrl+R	Reset the plot configuration
Ctrl+Shift+S	Copy plot to the clipboard as a spreadsheet (tab delimited)
Ctrl+U	Update the plot from the current input file
Ctrl+Y	Reset the y axis range to span the data plotted
Ctrl+Z	Reset both axes ranges to span the data plotted
F1	Invoke on-line help

Using TEdit

Start TEdit from the Support pane on the GWB dashboard, or by opening a ".tdat" or ".sdat" file.

TEdit is a graphical editor that lets you create and modify the thermodynamic and surface reaction datasets used by the GWB programs. You can alternatively use a simple text editor such as Notepad to modify the datasets. If you prefer to use a text editor, details of the datasets' formats are given in the Thermo Datasets appendix to the GWB Reference Manual.

With TEdit you can view and modify the entries in a dataset, as well as add or delete them. Specifically, you can alter

- Header lines, data tables, and dataset information.
- Elements and species in the dataset, and their properties.
- Reactions among the species, and log Ks at the principal temperatures.
- Virial coefficients for pairs or triplets of species.

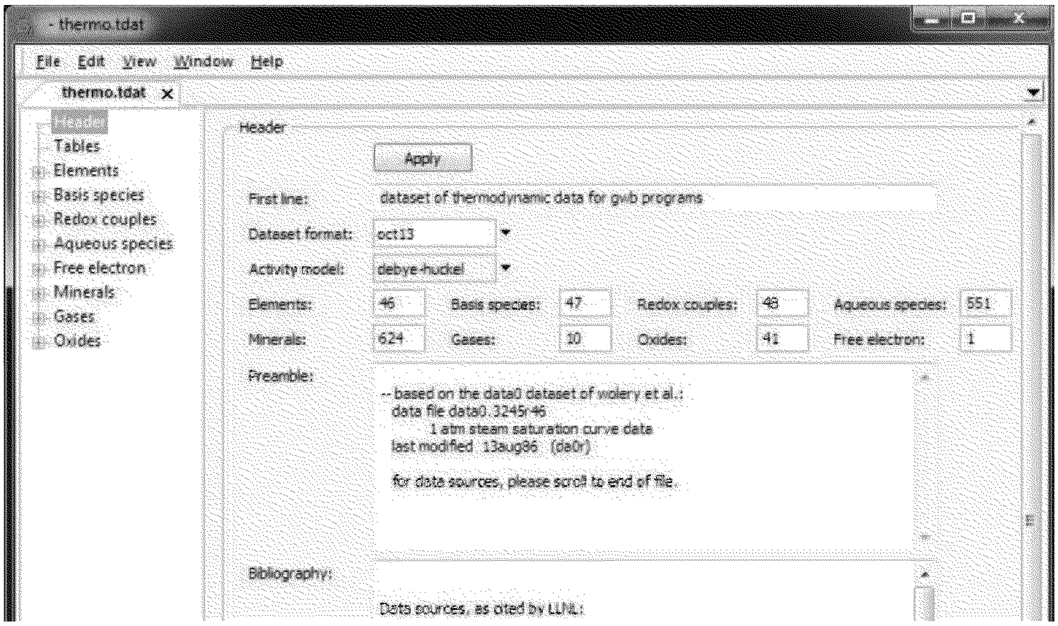
You can also:

- Identify entries containing or consisting of specific elements, basis species, or redox species.
- Swap basis species as you add reactions for new entries.
- Copy entries from one dataset to another.
- Rebalance existing reactions, including altering the coupling of redox reactions.
- Exchange the locations of basis, redox, and aqueous species.

9.1 Getting Started with TEdit

9.1.1 Viewing a thermo dataset

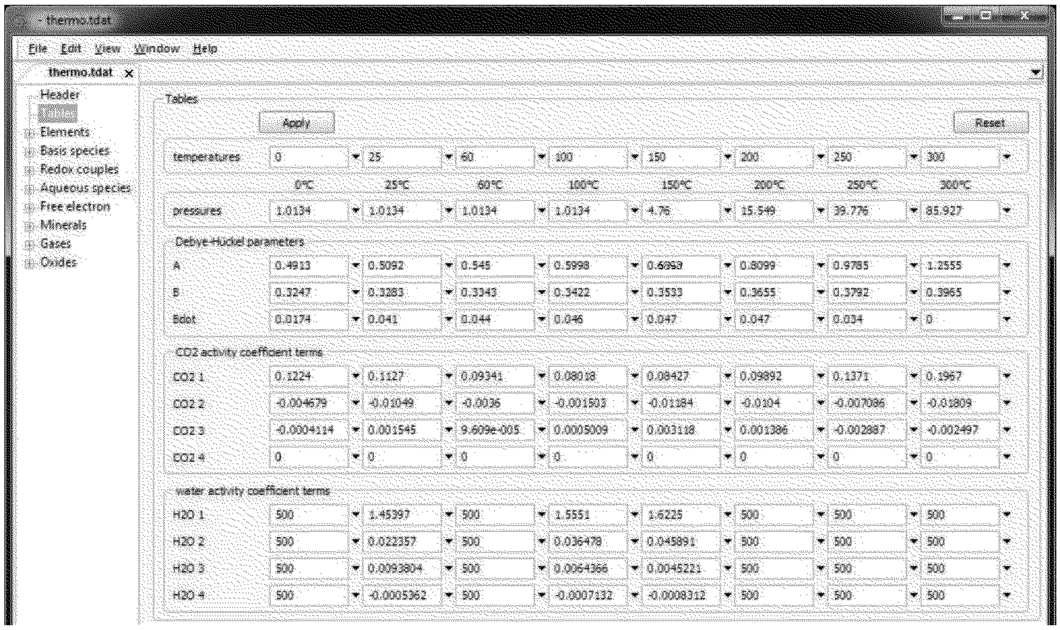
To open TEdit, go to the Support pane of the GWB Dashboard and click the "Edit thermo data" button. Then goto File ! Open ! Thermo Data... and browse toopen an existing dataset. You can also double-click any ".tdat" file to open it in TEdit. Or, you can open the thermo dataset currently loaded in any GWB program by going to File ! View and selecting the file ending in ".tdat". The dataset might look like this:



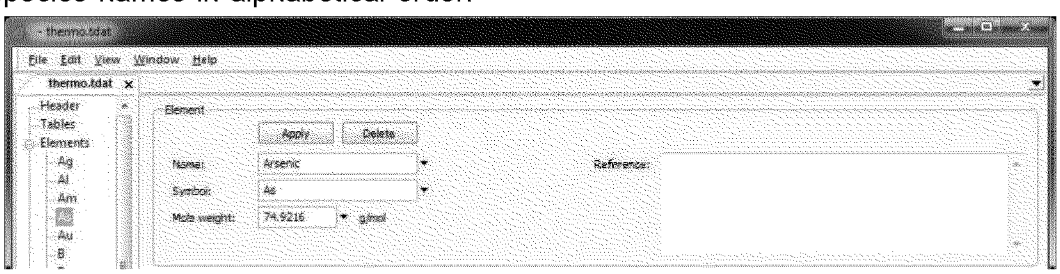
On the left side of the window is a tree structure with sections labeled "Header", "Tables", "Elements", "Basis species", "Redox couples", "Aqueous species", "Free electron", "Minerals", "Gases", "Oxides", and optionally "Virial coefficients". For detailed descriptions of each section see the Thermo Datasets appendix in the GWB Reference Manual.

Click"Header"onthetreetoviewthedatasetformat,activi tymodel,andbibliographic information. The pane also shows the number of elements, basis species, and so on in the dataset. Click on one of the numbers to navigate to the corresponding section of the dataset.

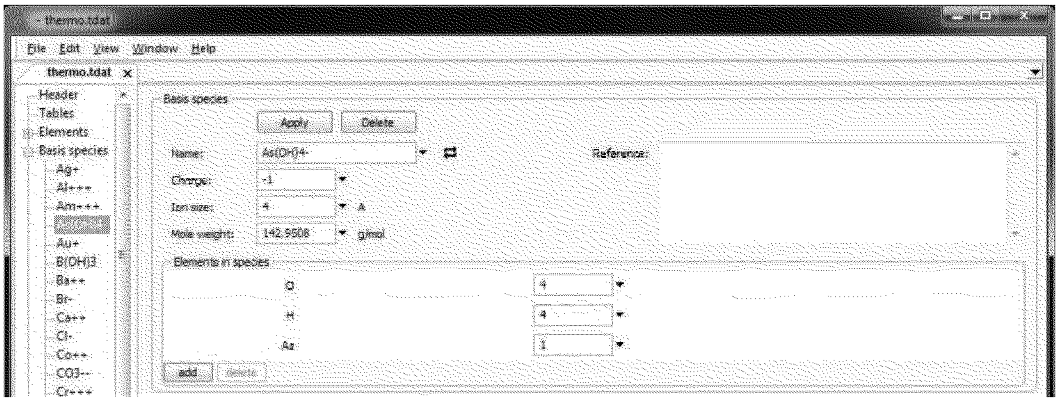
The next section contains tables showing how various coefficients used by the programs vary with temperature. The eight principal temperatures of the dataset are set in the top line of this section.



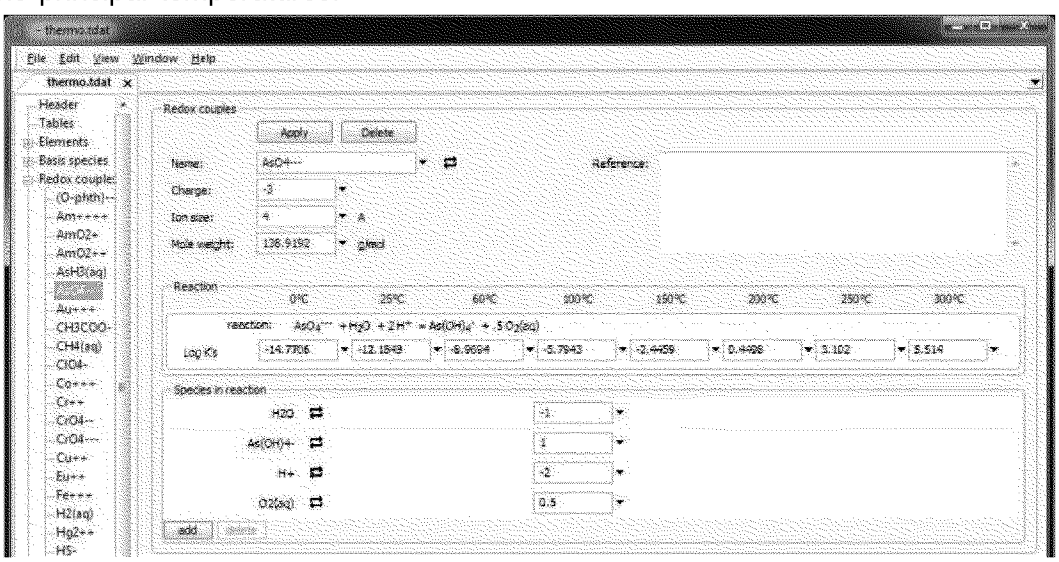
The following section contains the list of elements from which species in the dataset can be created. Click the "+" button to expand the list. Each element's entry contains a name, symbol, and molecular weight. TEdit lists element symbols and species names in alphabetical order.



The "Basis species" are listed in the next section. Each entry contains a name, charge, ion sizeparameter inangstroms (plus asecond b term for activitycoefficients in the phreeqc, minteq, and wateq4f activity models), and mole weight in the labeled text boxes, as well as its elemental composition.

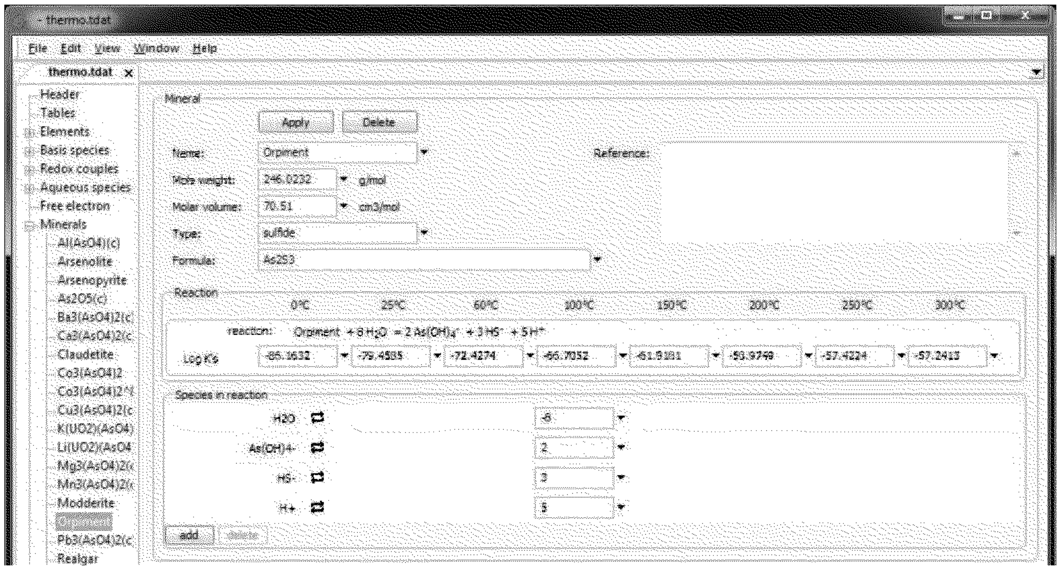


The “Redox couples” are similar to the Basis species, except that redox couples are constructed from existing species, rather than from the elements. The species form a balanced reaction for which equilibrium constants are supplied at each of the principal temperatures.



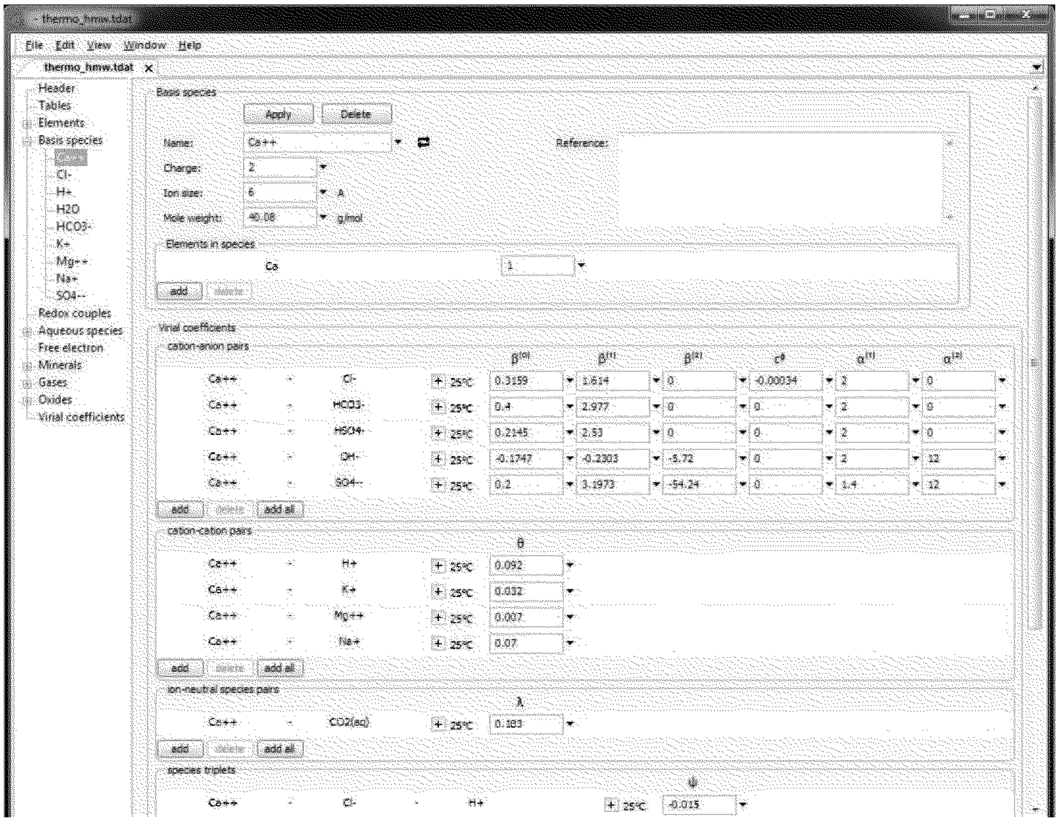
“Aqueous species”, “Free electron”, “Minerals”, “Gases”, and “Oxide” components are added in a similar manner to redox couples, with a few differences. The name, charge, ion size parameter, and mole weight of the free electron cannot be modified, although you can modify its reaction and log Ks, as you would for any other species.

Minerals have fields for entering the mineral’s molar volume, type, and chemical formula. Minerals, gases, and oxide components do not have fields for charge or ion size parameter. The oxide components do not have thermodynamic stabilities, so there is no place to enter log K values.

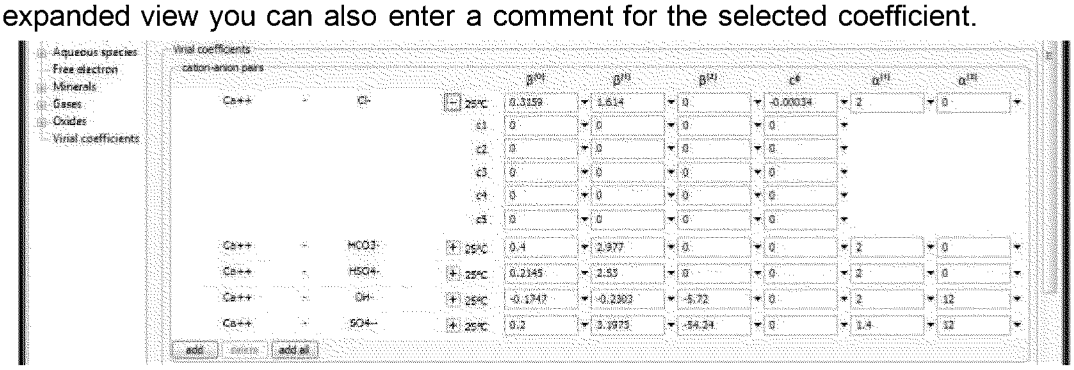


Datasets that utilize virial ("Pitzer") equations include coefficients describing the energeticinteractionsamongbasis,redox,andaqueousspe cies.Inthermo_hmw.tdat, for example, the entry for Ca^{CC} lists interaction terms with anions, cations, neutral species, and triplets of species. TEdit displays the interaction terms for various pair-wise and triplet combinations of species in the "Virial coefficients" section of the tree and under the entry for all involved species.

For example, Ca^{CC} and Cl Basis species both display theCa^{CC}-Cl cation-anion pair interaction terms, as well as all the triplets involving both species. If,while on the entry for Ca^{CC}, you apply changes to the Ca^{CC}-Cl pair coefficients, the changes will be reflected on the entry for Cl and on the Ca^{CC}-Cl pair's entry on the tree as well.



Each coefficient is listed at 25°C. You can click the "+" button to enter up to five additional coefficients to account for temperature effects (see Virial Coefficients under the Thermo Datasets appendix in the GWB Reference Manual). While in the expanded view you can also enter a comment for the selected coefficient.



9.1.2 Viewing a surface dataset

In TEdit, go to File ! Open ! Sorbing Surfaces... and browse to open an existing surface dataset. You can alternatively open an ".sdat" file in TEdit by double-clicking on it. Or, from one of the GWB modeling programs, choose File ! View and select any currently loaded surface dataset.

Surface datasets are organized much like thermo datasets, and can be navigated in TEdit using a similar tree structure.

9.1.3 Creating new datasets

To create a new thermo dataset, go to File ! New ! Thermo Data and select an activity model. TEdit can format GWB datasets that invoke variations of the Debye-Hückel equations or the virial techniques (see Thermodynamic Datasets under Configuring the Programs, and Activity Coefficients under Using SpecE8). Note the "Pitzer" format is outdated and not recognized by TEdit; it has been superceded by the "h-m-w" format.

To create a surface dataset, similarly, go to File ! New ! Sorbing Surfaces and choose one of the surface models (see Sorption onto mineral surfaces under Configuring the Programs). If you choose to create an ion exchange dataset, you will need to pick as well an activity convention. You should set a unique "type" in the header section for each surface dataset you create. The "type" identifies the dataset within the GWB modeling programs, when more than one surface dataset has been loaded.

9.1.4 Dataset formats

Thermo datasets beginning with the GWB 10 release are distributed in the "oct13" format. TEdit canread and writedatasets in that format,which ispreferred for current installations of the software, or in various legacy formats (see Legacy formats under the Thermo Datasets appendix in the GWB Reference Manual) for use with earlier releases of the software package.

The current format for surface datasets is "jan14". The format differs from legacy formats in that it identifies a thermo dataset from the which the species are drawn to make up surface reactions. The header lines in surface dataset "FeOH_minteq.sdat", for example, link it to the thermo dataset "thermo_minteq.tdat". TEdit, then, will look to "thermo_minteq.tdat" to find aqueous species to be used in balancing chemical reactions within "FeOH_minteq.sdat".

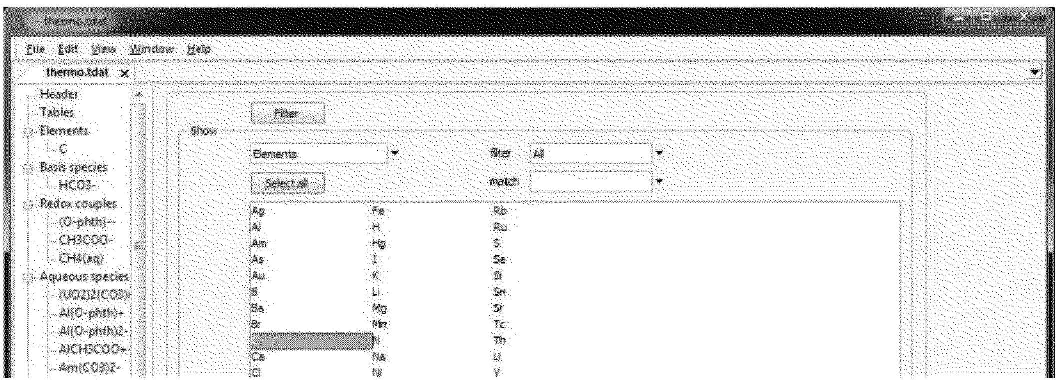
9.1.5 Saving datasets

Click File ! Save to save your thermo or surface dataset. TEdit will by default save thermo datasets as ".tdat" files, and surface datasets as ".sdat" files. To save a surface dataset to be used with GWB 9 or earlier releases, choose one of the legacy formats in the "Header" section and set a ".dat" extension in the Save As... dialog.

9.2 Working with datasets

9.2.1 Show

When you can click on any section (except "Header" and "Tables") on TEdit's tree structure, the program will display a pane that allows you to filter the species displayed on the tree. You can choose to show only entries containing specific elements, or those composed of specific basis and redox species.



To filter the species shown in the tree, select either "Elements" or "Basis and redox species" from the pulldown to the upper left of the filter pane. Choose one or more options below, then click on the "Filter" button. To return to showing all the entries, choose "Select all" followed by "Filter".

9.2.2 References

From the "Header" section you can add comments to appear at either the beginning of a dataset, or at the end. Text you type into the "Preamble" appears just below the Header lines at the top of the dataset, whereas the contents of the "Bibliography" appear at the bottom. If you would like to add comments or a reference to an individual species in the dataset, open the species' data pane, enter text in the "Reference" block, and click Apply.

9.2.3 Add and delete entries

To add an element or a species to a dataset, right-click on the appropriate section heading in the tree and choose "Add". Complete the data template that appears, and click Apply to preserve your changes. The new entry will appear alphabetically within the tree, as well as within the dataset when you save it.

To remove an entry from a dataset, right-click on its label in the tree and choose "Remove". Alternatively, click on the "Delete" button within the entry's data pane. If the reactions to form other species in the dataset contain the entry you are deleting, a dialog box will appear listing those species. You may choose "OK" to delete all the species, or "Cancel" to retain them.

9.2.4 Completing entries in thermo datasets

When adding an element to adatabase, you enter a name, symbol, and mole weight. For basis species, you fill in the species' name, charge, ion size parameter, b term, if applicable, and mole weight. Last, click the "add" button to build up the species' elemental composition.

For the remaining entries, you set a balanced chemical reaction. In the "Species in reaction" section you click "add", choose a type of species (Basis..., Redox..., Aqueous. .., Electron..., Mineral..., or Gas...), then select a species. You repeat the procedure for each species that appears in the reaction, supplying a reaction coefficient in the space to the right of its name.

Species with a negative reaction coefficient appear on the reaction's left-hand side; those with a positive coefficient are on the right. As you add species, the reaction is automatically written out. In the fields below the reaction, set a log K for each reaction, as well as its temperature derivative.

For virial datasets (those invoking the "Pitzer equations"), you further enter coefficients reflecting pair-wise and triplet interactions among the species. You can specify interaction terms for cation-anion pairs, cation-cation or anion-anion pairs, ion-neutral species pairs, and species triplets on the data pane for any basis, redox, or aqueous species. Click "add" in the appropriate section and select a pair or triplet from the pulldown list. Fill in values for some or all of the coefficients (see Virial Coefficients in the Thermo Datasets appendix to the GWB Reference Manual).

9.2.5 Completing entries in surface datasets

9.2.5.1 Two-layer datasets

Two-layer datasets are arranged much like thermo datasets. You start by adding one or more “Basis surface species”, for which you specify a name, charge, and mole weight. Each basis entry defines a sorbing site. Click “add” to define the site’s elemental composition, drawing from the list of elements in the thermo dataset, which is named in the dataset “Header”.

Secondly, you compile a list of surface complexes under “Surface species”. For each complex, you set a reaction written in terms of a basis species in the surface dataset, combined with basis, redox, and aqueous species drawn from the thermo dataset. You set a log equilibrium constant for each reaction (as a log K), as well as its temperature derivative.

Finally, you specify one or more minerals to carry the surface. Right-click on “Sorbing minerals” and select “Add”. Each sorbing mineral may host an arbitrary number of sorbing sites, which are the basis species in the dataset. Next to “Name”, click “New Sorbing Mineral” ! “Minerals...” and choose a mineral from the thermo dataset. Enter the mineral’s specific surface area, in m^2 g ^{1}. Under sorption sites, click “add” to pull in the surface’s basis species; for each set a site density in mol (mol mineral) ^{1}.

You can specify a value for constant capacitance or constant potential, but not both, in the Header section. You may prefer to leave these unset and allow the user to set values as desired from within Rxn, SpecE8, React, X1t, or X2t (see Two-layer surface complexation model under Configuring the Programs).

9.2.5.2 Langmuir datasets

Langmuir datasets contain a single basis entry, which represents the sorbing site. The Langmuir site is uncharged and carries no mass, so you need enter only a name. You can load any number of Langmuir datasets simultaneously into the GWB modeling programs, as long as each has a unique “type” set in the “Header”, and a unique name for the basis entry.

To define the surface complexes, right-click on “Surface species” and choose “Add”. Then, click in the “Species” box and choose a species to complex with the surface site. TEdit will construct a balanced reaction including the Langmuir site and will fill in all the entries, except for the equilibrium constant. You enter values for log K and its temperature derivative.

9.2.5.3 K_d and Freundlich datasets

K_d andFreundlichsurfacedatasetsinclude surfacecomplexes,butnotbasisspecies. To define a surface complex, right-click on “Surface species” and choose “Add”. Click in the box to the right of “Species:” and choose from the basis, redox, and aqueous species in the thermo dataset. TEdit automatically completes the entry, except for the K_d, or the values of K_f and n_f, which you enter yourself.

9.2.5.4 Ion exchange

An ion exchange dataset contains a single basis species. To define it, right-click on “Basis species” and choose “Add”. In the box to the right of “Sorbed species”, choose from the list of basis species in the thermo dataset. TEdit will automatically complete the entry.

To define the surface species that exchange with the basis species, right-click on “Surface species” and select “Add’. Click in the box to the right of Species and choose from the list of species in the thermo dataset. TEdit will construct a balanced reaction following the activity convention you have chosen, and fill in all entries except for the selectivity coefficient, which you enter as a linear value.

9.2.6 Transferring dataset entries

You can transfer data tables, elements, any type of species, or virial coefficients from one dataset to another. Copy an entry to the clipboard by right-clicking it on the tree structure and selecting “Copy”. Alternatively, select an entry and click on Edit ! Copy. Edit ! Cut performs a similar function, but removes the entry in question from the source dataset.

To paste, click anywhere on the tree structure of the target dataset and go to Edit ! Paste. You do not need to worry about selecting the specific location in a target dataset to paste your entry, because TEdit copies this information to the clipboard.

You can also drag entries (see Drag and drop under Introduction) from one dataset to another. Left-click an entry on the tree structure of the source dataset, drag to the tree structure or current entry of the target dataset, and release. If the source and target datasets are open in the same TEdit window, switch to the target dataset by hovering over its tab while dragging.

You should use your judgment when transferring thermodynamic data from one dataset to another. TEdit will issue a warning when activity models differ and will not allow you to transfer data in some cases. For example, you cannot transfer virial coefficients to a Debye-Hückel based dataset. Similarly, the program will not allow you to transfer surface species, unless both datasets use the same surface model. For example, you cannot transfer a reaction for sorbed Pb^{CC} from a K_d to a two-layer model dataset.

TEdit will issue a warning if you try to transfer an entry that would be undefined in the target dataset. For example, you would need to add the element Cadmium to “thermo.tdat” before you can paste in the basis species Cd^{CC}. Similarly, a dataset utilizing the virial equations must include the Ca^{CC} and Cl species before you can paste the Ca^{CC}-Cl cation-anion pair interaction term.

TEdit will transfer only log Ks corresponding to exact temperature matches when two datasets are compiled at different principal temperatures. If the source and target datasets use different sets of basis and redox species, TEdit will attempt basis swaps to rebalance the reaction, as described below.

9.2.7 Basis swapping

The GWB programs require the reactions in a thermo dataset be written in terms of basis species, redox species, the gaseous form of the redox pivot, and the free electron(see Redox couples andlatersectionsunder the Thermo Datasets appendix in the GWB Reference Manual).

Reactions you find in the literature may not conform to this convention, but TEdit can quickly convert them, by swapping the basis. You might, for example, find a deprotonation reaction written in terms of the hydroxyl ion OH , even though you are working with a dataset that carries H^{C} rather than OH in the basis. When you enter the reaction as written, TEdit replaces OH in the reaction with H^{C} and recalculates the reaction’s log Ks. For more information about basis swapping, see Setting and constraining the basis under Configuring the Programs.

Suppose we want to add to dataset “thermo.tdat” the aqueous species $FeCl_3$, given the reaction

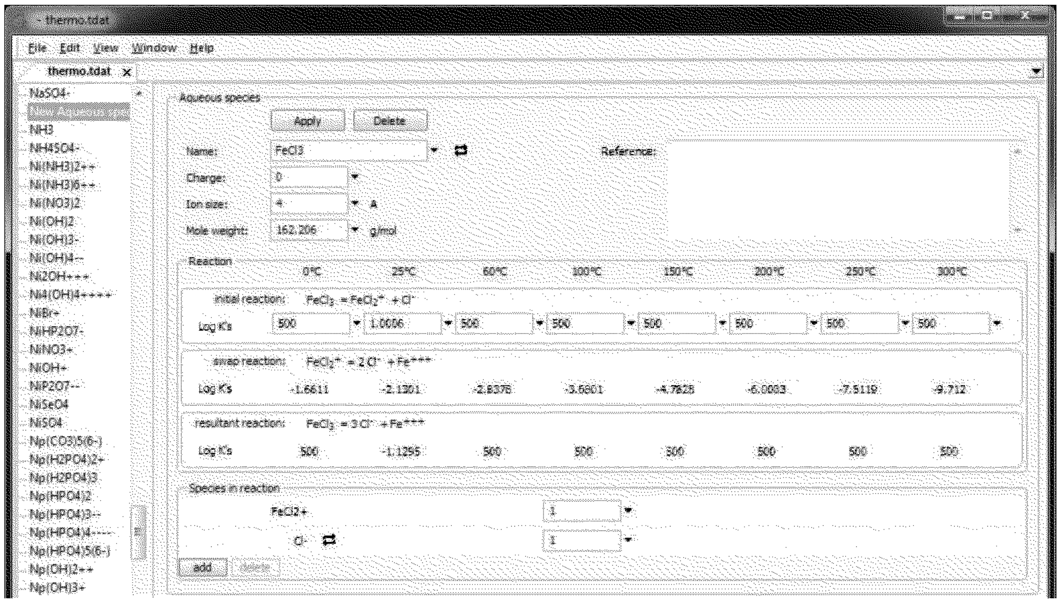
$$FeCl_3 \quad FeCl_2^{C} \, C \, Cl \;\; ; \quad \log K \; D \; 1{:}0006 \text{ at } 25^{\prime}C \qquad (9.1)$$

Right click on “Aqueous species” and choose “Add”. In the blank pane that opens, type “FeCl3(aq)” as the species name. Enter the reaction above by clicking add ! Aqueous... ! “FeCl2+” and add ! Basis... ! “Cl-”. Set a reaction coefficient of 1 for each and enter the log K value above.

Note how TEdit automatically swaps out the aqueous species $FeCl_2^{C}$ for the redox species Fe^{CCC} and recalculates the reaction’s equilibrium constant

$$FeCl_3 \quad 3Cl \;\; C \, Fe^{CCC} ; \log K \; D \quad 1{:}1295 \text{ at } 25^{\prime}C \qquad (9.2)$$

to reflect the new reaction. Before you click Apply to preserve your changes, your window should look like this:



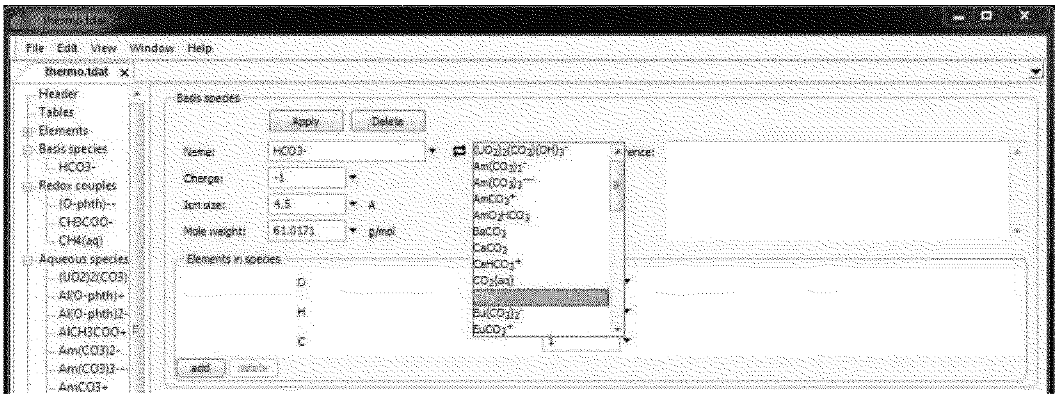
You can equally employ TEdit's basis swapping capabilities to rebalance existing reactions. You may wish to convert a redox reaction balanced in terms of O_2(aq), for example, to a half-cell reaction. To do so, choose a redox species from the tree and look at the species that appear in its reaction. Click the "swap" button next to "O2(aq)" and select "Electron. ..", if the option is available. If it is not, first swap "O2(g)" in for "O2(aq)", click Apply, then swap in the electron for "O2(g)". Click Apply to use the rebalanced reaction and updated log K. Whether the rebalancing can be performed in one or two steps depends on whether the reaction for the free electron is written in terms of the aqueous or gaseous form of the redox pivot.

9.2.8 Exchanging species

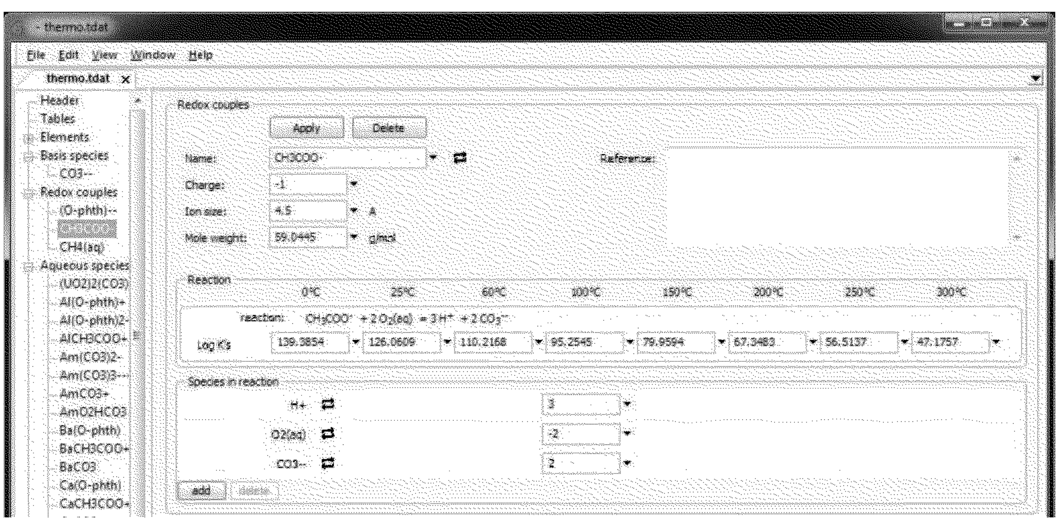
You can use TEdit to exchange the positions of basis, redox, and aqueous species within a thermo dataset. For example, you might replace the basis species "HCO3-" with the aqueous species "CO3--". In this case, "CO3--" will appear in the basis, and "HCO3-" among the aqueous species; all of the reactions in the dataset that had been written in terms of "HCO3-" will instead involve "CO3--".

To exchange the positions of two species, choose the first from the tree structure to expose its data pane. Click the "swap" button next to the species' name, select the type of species to exchange with, then choose from the pulldown list the second of the species. TEdit exchanges the species' position in the dataset, as you can see in the tree structure, and rewrites the reaction between them. Dependent reactions throughout the dataset will be rebalanced, as well.

To perform the "CO3--" for "HCO3-" swap described above, for example, choose "HCO3-" from the tree and, next to its name on its data pane, click ⇄ ! Aqueous... ! "CO3--", as shown below:



You could accomplish the same thing in reverse, by selecting "CO3--" from the tree and swapping in "HCO3-". In either case, note that after the exchange, any reactions originally written in terms of "HCO3-" will have been rebalanced, as shown below for "CH3COO-":



The exchange feature provides a quick method for changing the redox pivot of a thermo dataset (see Basis species under the Thermo Datasets appendix in the GWB Reference Manual). In "thermo.tdat", when you exchange the basis species O_2(aq) for the redox species H_2(aq), the latter becomes the redox pivot. The reaction for the free electron as well as the redox coupling reactions written in terms of dioxygen will be rebalanced in terms of dihydrogen.

The order in which species are selected for exchange does not matter. If you were to exchange the same two species a second time, the dataset would revert to its original state. H_2O is required as an entry in the basis and has therefore been excluded from the exchange feature.

Appendix: Further Reading

Thefollowingliteraturereferences, fromthemanyhundred s thathavebeenpublished, provideastartingpointforfurtherreadingonvariousaspe ctsofgeochemical modeling anditsapplications.Additionalreferencesareavailable inthe GWB Reaction Modeling Guide and GWB Reactive Transport Modeling Guide.

A.1 Natural waters

Garrels, R.M. and M.E. Thompson, 1962, A chemical model for sea water at 25°C and one atmosphere total pressure. American Journal of Science 260, 57-66.

Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water. U.S. Geological Survey Water-Supply Paper 2254, 263 p.

Kharaka, Y.K and I. Barnes, 1973, SOLMNEQ: Solution-mineral equilibrium computations. U.S. Geological Survey Computer Contributions Publication 215-899.

Lindberg, R.D. and D.D. Runnells, 1984, Ground water redox reactions: An analysis of equilibrium state applied to Eh measurements and geochemical modeling. Science 225, 925-927.

Truesdell, A.H. and B.F. Jones, 1974, WATEQ, a computer program for calculating chemical equilibria of natural waters. U.S. Geological Survey Journal of Research 2, 233-248.

Westall, J.C., J.L. Zachary and F.M.M. Morel, 1976, MINEQL, a computer program for the calculation of chemical equilibrium composition of aqueous systems. Hydrodynamics Laboratory Technical Note 18, Massachusetts Institute of Technology, 91 p.

A.2 Speciation modeling

Bethke, C.M., 2007, Geochemical and Biogeochemical Reaction Modeling. Cambridge University Press, New York, 547 p.

Parkhurst, D.L., D.C. Thorstenson and L.N. Plummer, 1980, PHREEQE—A computer program for geochemical calculations. U.S. Geological Survey Water-Resources Investigations 80–96, 210 p.

Plummer, L.N., D.L. Parkhurst, G.W. Fleming and S.A. Dunkle, 1988, PHRQPITZ—A computer program incorporating Pitzer's equations for calculation of geochemical reactions in brines. U.S. Geological Survey Water-Resources Investigations Report 88–4153, 310 p.

Reed, M.H., 1982, Calculation of multicomponent chemical equilibria and reaction processes in systems involving minerals, gases and an aqueous phase. Geochimica et Cosmochimica Acta 46, 513–528.

Wolery, T.J., 1983, EQ3NR, a computer program for geochemical aqueous speciation-solubility calculations: user's guide and documentation. Lawrence Livermore National Laboratory Report UCRL-53414, 191 p.

A.3 Uniqueness of solutions

Bethke, C.M., 1992, The question of uniqueness in geochemical modeling. Geochimica et Cosmochimica Acta 56, 4315-4320.

A.4 Stability diagrams

Bowers, T.S., K.J. Jackson and H.C. Helgeson, 1984, Equilibrium Activity Diagrams. Springer-Verlag, Berlin, 397 p.

Garrels, R.M. and C.L. Christ, 1965, Solutions, Minerals, and Equilibria. Freeman, Cooper & Co., San Francisco, 450 p.

A.5 Activity models for electrolyte solutions

Harvie, C.E, N. Møller and J.H. Weare, 1984, The prediction of mineral solubilities in natural waters: The Na-K-Mg-Ca-H-Cl-SO_4-OH-HCO_3-CO_3-CO_2-H_2O system to high ionic strengths at 25°C. Geochimica et Cosmochimica Acta 48, 723–751.

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A.6 Sorption, ion exchange, and surface complexation

Appelo, C.A.J. and D. Postma, 1993, Geochemistry, Groundwater, and Pollution. Balkema, Rotterdam, 536 p.

Dzombak, D.A. and F.M.M. Morel, 1990, Surface Complexation Modeling, Hydrous Ferric Oxide. Wiley, New York, 393 p.

Stumm, W., 1992, Chemistry of the Solid-water Interface. Wiley, New York, 428 p.

Stumm, W. and J.J. Morgan, 1996, Aquatic Chemistry, 3rd ed., Wiley, New York, 1022 p.

A.7 Thermodynamic database

Delany, J.M. and S.R. Lundeen, 1990, The LLNL thermochemical database. Lawrence Livermore National Laboratory Report UCRL-21658, 150 p.

Helgeson, H.C., J.M. Delany, H.W. Nesbitt and D.K. Bird, 1978, Summary and critique of the thermodynamic properties of rock-forming minerals. American Journal of Science 278-A, 1-229.

Johnson, J.W., E.H. Oelkers and H.C. Helgeson, 1991, SUPCRT92: A software package for calculating the standard molal thermodynamic properties of minerals, gases, aqueous species, and reactions from 1 to 5000 bars and 0° to 1000°C. Earth Sciences Department, Lawrence Livermore Laboratory, 101 p.

Index

To: Krissy Downing Ex. 4
Jonathan.Koplos Ex. 4
From: Ridley, Caroline
Sent: Tue 5/5/2015 2:33:27 AM
Subject: RE: Edits to HF water cycle figure

Ex. 5

Thanks,

Caroline

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Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and Ex. 6

From: Krissy Downing Ex. 4
Sent: Monday, May 04, 2015 5:08 PM
To: Ridley, Caroline; Jonathan.Koplos Ex. 4
Subject: Re: Edits to HF water cycle figure

Ex. 5

Thanks!
~~~~~~

Krissy Downing | Senior Designer
The Cadmus Group, Inc.
Seattle, WA | Ex. 4

From: Ridley, Caroline <Ridley.Caroline@epa.gov>
Sent: Thursday, April 30, 2015 8:00 AM
To: Krissy Downing; Jonathan Koplos
Subject: RE: Edits to HF water cycle figure

Krissy- since it's just us, call me in my office. Number below.

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and Ex. 6

-----Original Appointment-----
From: Ridley, Caroline
Sent: Wednesday, April 29, 2015 1:24 PM
To: Krissy Downing; Jonathan Koplos
Subject: Edits to HF water cycle figure
When: Thursday, April 30, 2015 11:00 AM-11:20 AM (UTC-05:00) Eastern Time (US & Canada).
Where: Ex. 6
~~~~~~

To: Stanek, John[Stanek.John@epa.gov]; Frithsen, Jeff[Frithsen.Jeff@epa.gov]
Cc: Yost, Erin[Yost.Erin@epa.gov]
From: Ridley, Caroline
Sent: Tue 3/31/2015 2:44:28 PM
Subject: RE: HF Drinking Water Chapter Comments: Executive Summary & chapters 6-10 (Discussion part 1)

Not yet. Forthcoming. -C

~~~~~~

Caroline E. Ridley, PhD
Ecologist
US Environmental Protection Agency
Office of Research and Development
National Center for Environmental Assessment
Office: (703) 347-8506 and Ex. 6

From: Stanek, John
Sent: Tuesday, March 31, 2015 10:41 AM
To: Frithsen, Jeff
Cc: Ridley, Caroline; Yost, Erin
Subject: RE: HF Drinking Water Chapter Comments: Executive Summary & chapters 6-10 (Discussion part 1)

Anyone have the call-in phone number details yet?

From: Frithsen, Jeff
Sent: Tuesday, March 31, 2015 10:36 AM
To: Burke, Thomas; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Zambrana, Jose; Teichman, Kevin; Briskin, Jeanne; Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Weaver, Jim; Stanek, John; Jonathan.Koplos Ex. 4; Shari.Ring Ex. 4 MaryEllen.Tuccillo Ex. 4
Subject: RE: HF Drinking Water Chapter Comments: Executive Summary & chapters 6-10 (Discussion part 1)

Note: Tom will be discussion Chapter 6 and then Chapter 9 during the meeting that starts at noon. We may not get to other chapters in this first meeting.

Jeff Frithsen
USEPA-ORD-NCEA
703-347-8623 (office phone)

-----Original Appointment-----
~~~~~~

From: Burke, Thomas
Sent: Friday, March 27, 2015 1:02 PM
To: Burke, Thomas; Frithsen, Jeff; Smith, Kelley; Gibbons, Dayna; Matthews, Lisa; Zambrana, Jose; Teichman, Kevin; Briskin, Jeanne; Ridley, Caroline; LeDuc, Stephen; Burden, Susan; Weaver, Jim; Stanek, John
Subject: HF Drinking Water Chapter Comments: Executive Summary & chapters 6-10 (Discussion part 1)
When: Tuesday, March 31, 2015 12:00 PM-2:30 PM (UTC-05:00) Eastern Time (US & Canada).
Where: Ex. 6

CT: Nathan Gentry

Teleconference: Details TBD

Staff:

Notes: Discussion of comments for Chapters 6-10 and executive summary

To: Knightes, Chris[Knightes.Chris@epa.gov]
From: Ridley, Caroline
Sent: Thur 2/26/2015 2:05:51 PM
Subject: RE: thoughts on Chapters 1 and 2

Thanks Chris Ex. 5

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays): Ex. 6

From: Knightes, Chris
Sent: Wednesday, February 25, 2015 4:26 PM
To: Ridley, Caroline
Subject: thoughts on Chapters 1 and 2

Ex. 5

Chapter 1:

Ex. 5
~~~~~~

Ex. 5

Ex. 5

To: Shari Ring Ex. 4 ; Frithsen, Jeff[Frithsen.Jeff@epa.gov]
From: Ridley, Caroline
Sent: Thur 2/26/2015 1:05:12 PM
Subject: RE: EPA Computer Hardware "Refresh"

Ex. 5

Ex. 6

Caroline

~~~~~~

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National Center for Environmental Assessment

Office: (703) 347-8506 and AWL (Fridays) Ex. 6

From: Shari Ring Ex. 4
Sent: Thursday, February 26, 2015 7:18 AM
To: Frithsen, Jeff
Cc: Ridley, Caroline
Subject: RE: EPA Computer Hardware "Refresh"

Ex. 5
~~~~~~

Ex. 5

Shari Ring

The Cadmus Group, Inc.

Ex. 4

From: Frithsen, Jeff [mailto:Frithsen.Jeff@epa.gov]
Sent: Wednesday, February 25, 2015 9:14 PM
To: Shari Ring
Cc: Ridley, Caroline
Subject: RE: EPA Computer Hardware "Refresh"

Ex. 5

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Shari Ring Ex. 4
Sent: Wednesday, February 25, 2015 9:09 PM
To: Frithsen, Jeff
Subject: Re: EPA Computer Hardware "Refresh"

Non-Responsive

Jeff

Jeff Frithsen

USEPA-ORD-NCEA

703-347-8623 (office phone)

From: Noel, Glenda **On Behalf Of** Blancato, Jerry
Sent: Wednesday, February 25, 2015 8:44 PM
Subject: News from OSIM - Hardware Refresh and More

ORD colleagues - The world of information technology and information management impacts everyone's daily lives. We use it, we abuse it, we are slaves to it, and it frees us to do other things. All these conflicting things and more are our way of life in the 21st century. At work the same is true. In our professional lives most of use EMAIL as our major mode of communication with people around the world as well as people just down the hall.

The OSIM staff is here to support you in many ways. We want you to know what we do, the latest developments and news of interest to you so you can do your job better. I am sure that often you wonder why the Agency, OSIM, and others do the things we do, require the things we require, and ask you the questions we ask. Our goal is to explain things as much as we can, because the more you know the easier all our jobs will be.

We also need to hear from you. As your needs change we need to change so we can meet those needs. It is not good for us to provide a service that you no longer find useful.

For these reasons and many more we are going to resume our "newsletters" to our customers. We plan to try a different format from the typical newsletter you often see. Periodically we will publish one or more "one pagers" with the latest information that we wish to convey. Those pages will not be attached to an email. Instead you will get an EMAIL message that an article or articles are available for you to read. You can choose to read any, all or none of them depending upon the topic. We will keep those articles available until we think they are out of date and no longer relevant.

For now, we would like to provide you an update on the ORD Hardware Refresh, this includes where we are, where we've been and where things are headed. We would also like to keep you updated on recent Records Management happenings and how they impact you.

Jerry N. Blancato, PhD

Senior Information Officer

US EPA Office of Research and Development

and

Director

Office of Science and Information Management

US EPA Office of Research and Development

919-541-2854

Blancato.Jerry@epa.gov

To: Frithsen, Jeff[Frithsen.Jeff@epa.gov]
From: Ridley, Caroline
Sent: Tue 2/24/2015 1:50:10 AM
Subject: FW: HFDWA PDF - part B

Ex. 5

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Office: (703) 347-8506 **Ex. 6**
~~~~~~

To: Mary Ellen Tuccillo Ex. 4
Cc: Jonathan.Koplos Ex. 4
From: Ridley, Caroline
Sent: Thur 2/19/2015 8:04:13 PM
Subject: RE: Jeanne's suggestions for deletions

Ex. 5

Caroline

~~~~~~

Caroline E. Ridley, PhD

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National Center for Environmental Assessment

Office: (703) 347-8506 Ex. 6

From: Mary Ellen Tuccillo Ex. 4
Sent: Thursday, February 19, 2015 10:11 AM
To: Ridley, Caroline
Cc: Jonathan.Koplos Ex. 4
Subject: Jeanne's suggestions for deletions

Hi Caroline,

Ex. 5
~~~~~~

Ex. 5

Mary Ellen

Mary Ellen Tuccillo, Ph.D.

The Cadmus Group

100 5th Ave., Suite 100

Waltham, MA 02451

Ex. 4

Water is the driving force of all nature. Leonardo da Vinci

Follow us on social media:

To: Jonathan Koplos Ex. 4
Cc: Anna Weber Ex. 4
From: Ridley, Caroline
Sent: Thur 2/19/2015 7:36:58 PM
Subject: RE: revised Chapter 2

Ex. 5

Thanks,

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 Ex. 6

From: Jonathan Koplos Ex. 4
Sent: Thursday, February 19, 2015 8:27 AM
To: Ridley, Caroline
Cc: Anna Weber
Subject: RE: revised Chapter 2

I've got calls from 9 to noon and 1 to 2 (with Jill re: FF and the well injection and produced
~~~~~~

water calls that Jeff asked me to join).

Rest of the day is flexible.

From: Ridley, Caroline [mailto:Ridley.Caroline@epa.gov]
Sent: Thursday, February 19, 2015 7:09 AM
To: Jonathan Koplos
Cc: Anna Weber
Subject: RE: revised Chapter 2

Ex. 5

Caroline

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 **Ex. 6**

From: Jonathan Koplos **Ex. 4**
Sent: Wednesday, February 18, 2015 7:55 PM
To: Ridley, Caroline
Cc: Anna Weber
Subject: revised Chapter 2
~~~~~~

Ex. 5

____

Jonathan Koplos, Ph.D.

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Ex. 4

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Follow us on social media:

SPE 166295

A Case History of Comprehensive Hydraulic Fracturing Monitoring in the Cana Woodford

T. Lowe, M. Potts and D. Wood, Devon Energy

This paper was prepared for presentation at the SPE Annual Technical Conference and Exhibition held in New Orleans, Louisiana, USA, 30 September–2 October 2013.

Abstract

In the Cana Field in Western Oklahoma, horizontal wells are completed with multiple hydraulic fractures to economically produce from the Woodford Shale. This field development program is relatively young, and previous fracturing optimization had been achieved by trial and error testing. Cana wells usually are drilled with a 5,000-ft lateral, which is hydraulically fractured in 10-20 stages utilizing the plug-and-perf method with multiple clusters per stage. Throughout the early field development, there has been significant uncertainty regarding various subsurface parameters including: fracture propagation geometry, cluster contribution, and interference remediation. This paper describes a comprehensive fracture monitoring project, which will be used to further the understanding of the hydraulic fracture geometry, interference, deliverability, and production.

In late 2012, the project well was drilled as part of the infill development program. In January 2013, the well was completed with a 12 stage slickwater frac. Several established and cutting edge technologies were used to assist with monitoring the hydraulic fracturing operation of the subject and offset wells. These technologies included: Distributed Temperature Sensing (DTS), Distributed Acoustic Sensing (DAS), prototype cemented frac valves, permanent bottom hole pressure gauge, surface micro seismic, down hole micro seismic, offset bottom hole pressure monitoring, logging-while-drilling, advanced open hole logging, radioactive tracers, and chemical tracers. These technologies were used successfully to monitor cementing operations, offset fracturing, monitor well fracturing, coiled tubing drill-out, flowback, and initial production. This project has assisted in the understanding of subsurface events and is expected to provide continued insight into long term production. Similar projects are being considered for the future, and this technology may ultimately become part of the standard completion.

This paper will focus on the planning, logistics, installation, and operation of this one of a kind monitoring project in the Cana Field.

Introduction

The Cana Woodford is an unconventional shale gas play located in western Oklahoma, with the first horizontal well being drilled in 2007. Full field development is now underway utilizing the two key technologies (horizontal drilling and hydraulic fracturing) which have been successful in the economic development of other shale gas plays. True vertical depths (TVD's) range from 12,000-ft to 14,500-ft and lateral lengths vary from 4,500-ft to 5,000-ft. These depths create unique challenges for design and implementation of the hydraulic fracturing program (Wood, 2011). Early exploration wells and delineation wells were often affected by high treating pressures and the inability to consistently place designed proppant volumes. To successfully develop this play, improvements to the hydraulic fracturing process were necessary. Through trial and error testing, methodologies were developed for more consistent placement of the designed stimulation treatments. Once this consistency was achieved, it opened the door for design changes aimed at improving well performance and recoveries.

Field development in Cana is based on individual sections, with each section encompassing one square mile. Initial field delineation was achieved by drilling one "parent" well per section, which in turn identified a "core" area of the field. This core area is now being developed by drilling an additional eight wells per section. Development is being achieved by drilling 2-3 wells per single location (pad) utilizing 12-16 drilling rigs and two full time frac crews. Wells are completed sequentially

As described earlier, the normal completion process in the Cana field is plug and perforations with multiple clusters. There was an obvious challenge to installing a fiber optic sensing line in a cemented horizontal wellbore and later perforating the casing. Due to the risk of perforating the fiber optic line the normal completion method needed to be altered. However, since this was a data gathering project, we wanted to closely imitate our "normal" completion method so that it could be evaluated. This imitation required that we have the well was cemented and fractured through multiple clusters per stage.

Over the course of several months, alternative completion techniques where evaluated. There was a perceived risk of inadvertently perforating the fiber line with oriented perforating, so the team decided to focus the evaluation on cemented sleeve systems. The team investigated options from many service companies. Two primary requirements were a 10,000-psi pressure rating and multi-valves opening. This evaluation resulted in a decision to perform a trial on two systems:

- Cemented, external casing gun system activated by ball drop seats
- Cemented, multi-cluster, ball drop sleeve system

The trial was arranged so that both systems would be installed in the bottom 3 stages (out of 10) in similar Cana wells. In these trial wells, fiber optics would not be installed and it was only a test of the completion system at Cana pressures and temperatures. The remaining 7 stages would be completed with the normal plug and perf method.

Several months before the comprehensive monitoring project started, the ball drop system was installed without any issues in the trial well. Immediately after installation, this well was hydraulically fractured with a slickwater treatment comparable in size to the planned McCray well. During the stimulation, pressure increases indicated that all valves operated as planned and the fracturing treatment proceeded without issues. In this trial well, fracturing break-down pressures for the cemented sleeve stages was equivalent to the plug and perf stages. Overall, this trial was a successful evaluation of the cemented multi-cluster sleeve system.

Due to issues with drilling the 2nd trial well, the external casing gun system trial was delayed until late in 2012. Because of this delay, the team decided to move forward with planning to use the cemented sleeve system for the fiber optic installation.

Complementing Technologies Selected

The objectives of the project required collecting information that assisted with the fiber optic analysis. Likewise, the team wanted to utilize known fracturing diagnostic tools to evaluate DAS/DTS fiber optic sensing accuracy. These additional technologies included:

- Microseismic
- Offset pressure monitoring for interference
- Proppant tracers
- Chemical tracers
- Openhole formation evaluation
- Production logs

Microseismic

Microseismic was planned from the beginning to be the best complimentary fracture diagnostic tool. The team geophysicist evaluated a large range of possible configurations and service providers who would result in the best results for the project objectives.

As a result of this evaluation, a two technology approach was selected. First, a downhole microseismic array would be installed in a neighboring new well. Second, surface microseismic arrays would be laid out over the McCray 2-26H well. By using these two technologies, the project team hoped to achieve a good fracture geometry analysis in all three dimensions (X, Y, and Z). Since the team did not have any direct experience with surface microseismic, this would also let us evaluate the data quality of surface microseismic compared to downhole microseismic.

The downhole microseismic acquisition would be installed deep in the vertical section of the neighboring well, which is located 600-ft west of the McCray 2-26H.

Proppant and Chemical Tracers

Chemical tracers and proppant tracers had been used previously in Cana and provided useful information in completion effectiveness. Based on this previous experience, the team wanted to further evaluate the accuracy of these diagnostic tools. Planned proppant tracers included iridium, antimony, and scandium. Chemical tracers would be collected during the flowback of all wells within 1 mile.

Open Hole Formation Evaluation

A key part of the project objectives was to understand the role of formation heterogeneity on hydraulic fracturing. This meant that data needed to be acquired about the heterogeneity of the formation. The team evaluated available options and how they could be used without jeopardizing drilling operations or the fiber installation. The team elected to collect standard triple-combo type open hole logs using Logging While Drilling (LWD) tools. After the well reached total depth, a single drill pipe conveyed logging operation would be performed, which included an ultrasonic borehole imager, azimuthal sonic tool, and an oil-based micro image tool.

Planning the Fiber Installation

Because a ball drop sleeve completion method was selected, the installation planning was significantly more complicated than the traditional Cana casing installation. An installation featuring any new technology can be difficult enough, but when several new technologies are combined, it is very easy to make mistakes. A minor mistake could result in lost rig time, but a major mistake could potentially cause complete project failure. As detailed above, an array of complementary technologies was planned and they all required that the fiber would be installed correctly and to full depth. Similar to the standard Cana Woodford design, the installation featured 5-1/2" production casing, using a "toe initiator sleeve" to facilitate quick and efficient fracturing operations without a tubing conveyed perforation (TCP). But, that is where the standard part of the installation ended.

As described earlier, a cemented multi-cluster sleeve system featuring 37 specifically spaced valves and a 10,000-psi burst rating was selected. The fiber must be installed on the outside of casing continuously from terminus to surface, so obviously, it must pass each valve along the way. This created concern for an upset with a high wear rate located right at the large valve OD that could potentially damage the line as it is being run in the hole. Also, being close to the ports themselves during treatment raised the requirement for improved fiber optic line protection. To combat both concerns, the valve design was modified to include a channel for the 11mm encapsulated fiber line in a 120° "blanked" positioned between the ports. However, to meet the burst design requirement the valve bodies would be enlarged radially to compensate for the reduction in wall thickness near the channel. See Figure 3. Including the toe initiator sleeve, the planned completion included were 38 valves, each approximately 4' in length with a 7.6" OD. In the heel of the well, an eccentric 7.75" OD pressure gauge mandrel required its own ¼" stainless control line to surface.

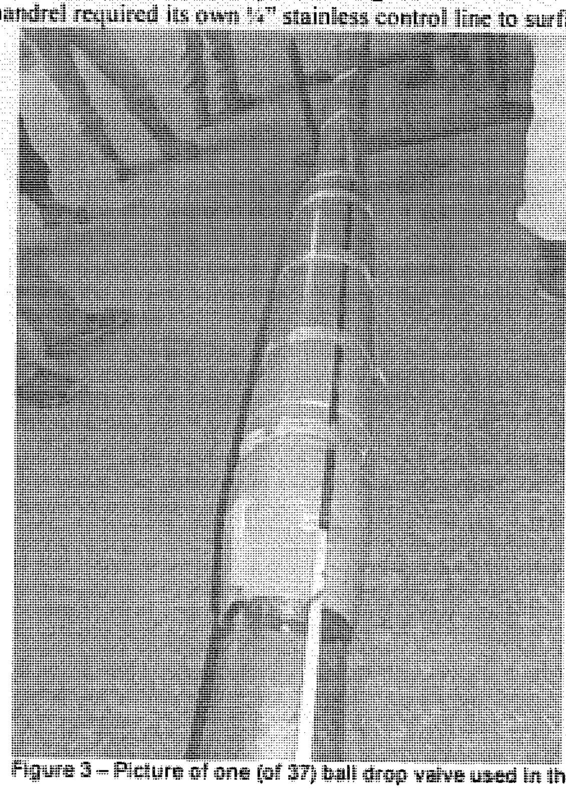

Figure 3 – Picture of one (of 37) ball drop valve used in the project.

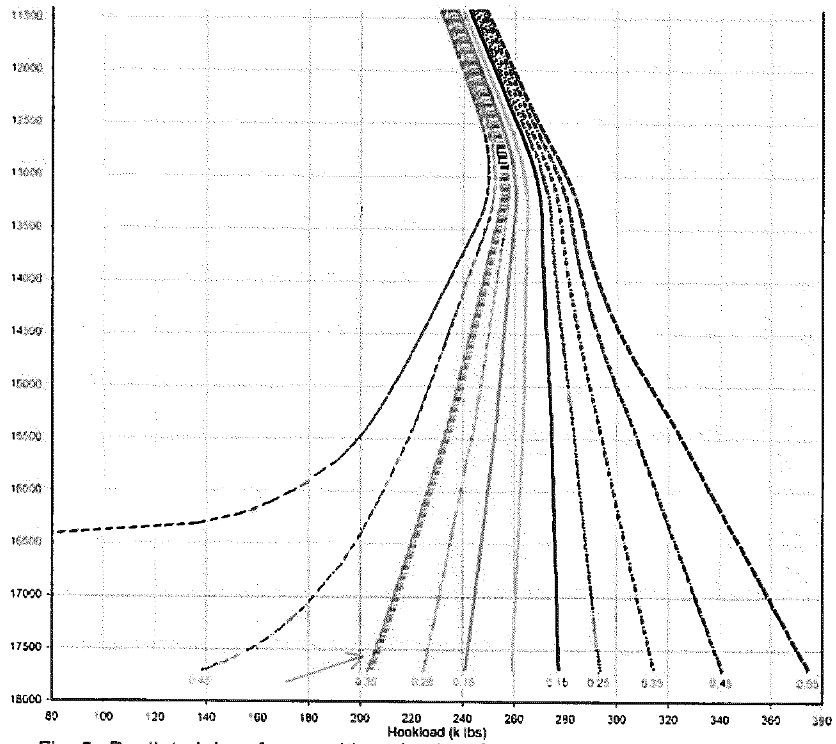

Fig. 5. Predicted drag forces with revised surface hole location.

In many situations, what is considered an acceptably clean hole to drill ahead, trip a BHA without a stuck pipe incident, and run casing to total depth, can vary dramatically when larger than normal completion tools or stabilizers with reduced junk slot area are integrated into the design. Tolerated residual cuttings load is relative and will likely have to be reduced before attempting an installation of this type. Backreaming of drilling BHAs can carry a negative connotation, but many times that is the result of poorly executed unplanned backreaming implemented as a response to poor hole conditions. Backreaming may increase risk in some aspects, but it can also produce the cleanest possible wellbore and as such it was integrated successfully into the clean-up protocols. Backreaming from TD with the highly stabilized RSS and LWD BHA proved to be one of the most challenging aspects of the entire procedure.

While rotary steerable systems, backreaming, and other enhanced clean-up techniques can produce a relatively clean wellbore, it is virtually impossible to completely remove all debris, especially a one mile horizontal wellbore. That being the case, stabilizer and centralizer design was not overlooked. The directional company and drilling engineer worked together to select and model stabilizers that had sufficient standoff and junk slot area but also had a minimum amount of spiral wrap. Excessive spiral wrap, especially when combined with small junk slot area, can add significant risk when attempting to pass thru any appreciable amount of cuttings. This consideration was also used for centralizer selection. Previous centralizer modeling suggested that 65-85% standoff was achievable using a relatively tight centralizer spacing regime thru the lateral and curve. Tight centralizer spacing has historically been used to improve cement quality, but in this application, it also decreases the likelihood of fiber cable wear. A straight blade centralizer with a large junk slot design also increases the ability to move thru residual cuttings beds instead of acting to plow them ahead. The final design criterion was that the centralizers could not be allowed to move or rotate independently of the string. Consequently, the selected centralizers had 10 total blind set screws to keep them from spinning on the casing. Shop testing suggested that at least 8,000ft-lbs of torque was necessary to spin the centralizer when properly installed. In the vertical portion of the wellbore, centralizers were not necessary and instead a "cross coupling clamp" would be used to protect the cables and hold the lines to the casing. The centralizers and cross coupling clamps are shown in figure 6.

the companies' office and field personnel to discuss, raise concerns, and ultimately find solutions to potential problems. A single ball drop valve, fiber cables, centralizers, casing, and the pressure gauge carrier were assembled at the casing crew's facility. Once the team was able to see and feel the downhole components, the best surface handling equipment was selected. The team was also able to build a list of action items and to document what equipment would be delivered to the wellsite.

Figure 8 – Field and office project members participate in "walk thru" at casing company's facility.

From there, the group traveled to the wellhead provider's facility and performed a full stack up of the wellhead equipment. The standard Cana wellhead required modification to accept the fiber and control lines. Setting the slips, installing the packoff, and terminating the lines were all rehearsed and multiple small issues were identified and remediated. See figure 9. Finally, the group traveled to the drilling rig to inspect actual conditions at the wellsite. An existing, completed surface installation was also visited to identify any potential surface installation issues.

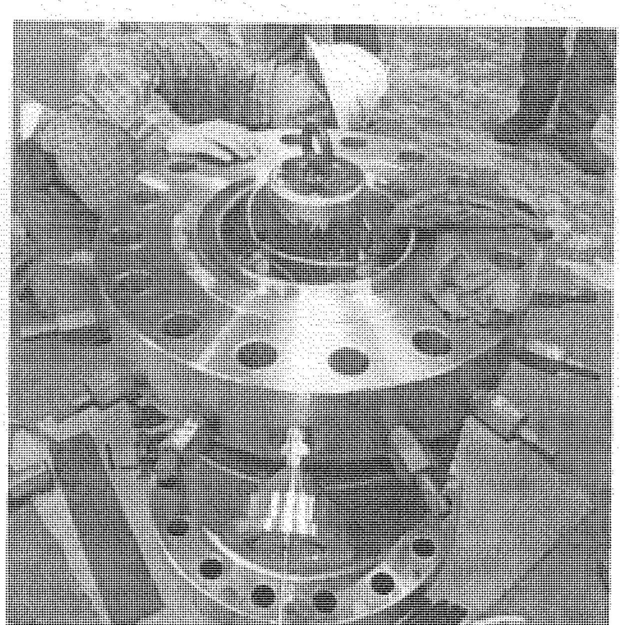

Fig. 9. Drilling Superintendent Inspects the modified wellhead during the dry stack up of wellhead components at service company's facility.

Another shop test and walk through found a deficiency involving the backup plan in case the valve system failed or if the seats had to be drilled out prior to completing all stages. While it had been assumed that two braided wire cables installed along either side of the fiber optic line could be located if oriented perforating became necessary, shop testing indicated logging tools were not capable of detecting the cable. Steel rods were then welded inside the cable clamps, and subsequent testing indicated they should be detectable if needed.

Because of all the upfront design work and coordination, actual installation was destined to be successful with minimal errors.

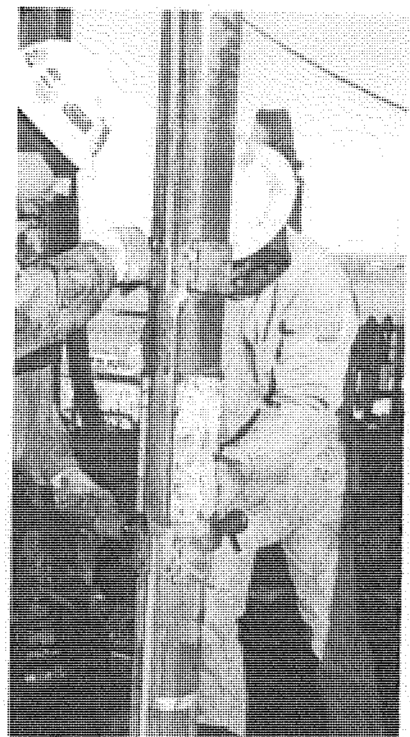

Fig. 11. Service company personnel install a cross coupling clamp.

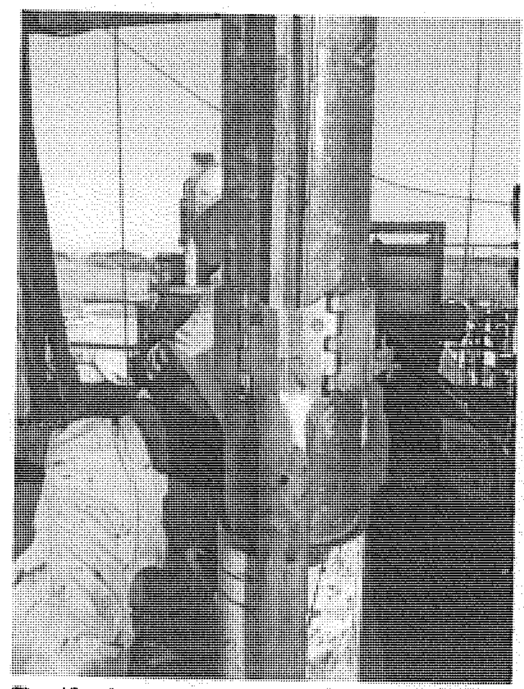

Fig. 12. A cross coupling clamp holds the yellow fiber optic line and the BHP gauge line to the 5-1/2" casing.

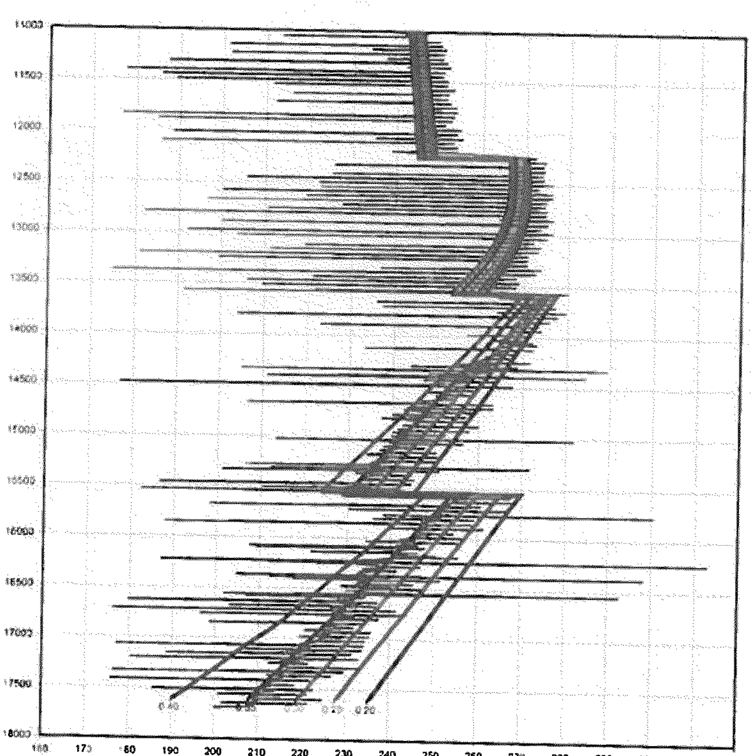

Fig. 13. This drag analysis chart shows the actual and modeled drag forces during installation with casing fill-ups included.

requirement meant that another barrier needed to be installed downhole. Consequently, a retrievable bridge plug was ran on e-line and tested after the packer was installed.

On January 18th, the downhole microseismic array was deployed in the McCray 3-26H. Immediately after this deployment, Vertical Seismic Profile (VSP) was acquired. This zero-offset ZSP utilized a vibrator truck located near the edge of the McCray 3-26H wellsite. Ultimately, this array remained deep in the vertical section of the wellbore, with the bridge plug and packer directly below the array tools.

After the VSP data had been acquired, multiple string shots were performed. These string shots were needed because the subject well would not be perforated. The first of these string shots, which utilized 80' of explosive primer cord, was conducted in the heel of the McCray 1-26H. This string shot was attempted twice, but the signal was too weak during both attempts to be utilized by downhole microseismic, which was located in the McCray 3-26H vertical, approximately 1 mile north. A third string shot was performed in the heel of the subject well, McCray 2-26H, later that night. The signal in this attempt was sufficient to help calibrate the velocity profiles for both surface and downhole microseismic companies.

The following day, fracturing operations began on the McCray 2-26H. This well was fractured in 12 stages, with various cluster (valve) spacing and configurations. Fracturing was monitored real time with the BHP gauge, DTS, DAS, and surface microseismic. During the fracturing operations, the three proppant tracers (Sc, Ir, Sb) were alternated into each stage. Likewise, individual chemical tracers were included in each stage.

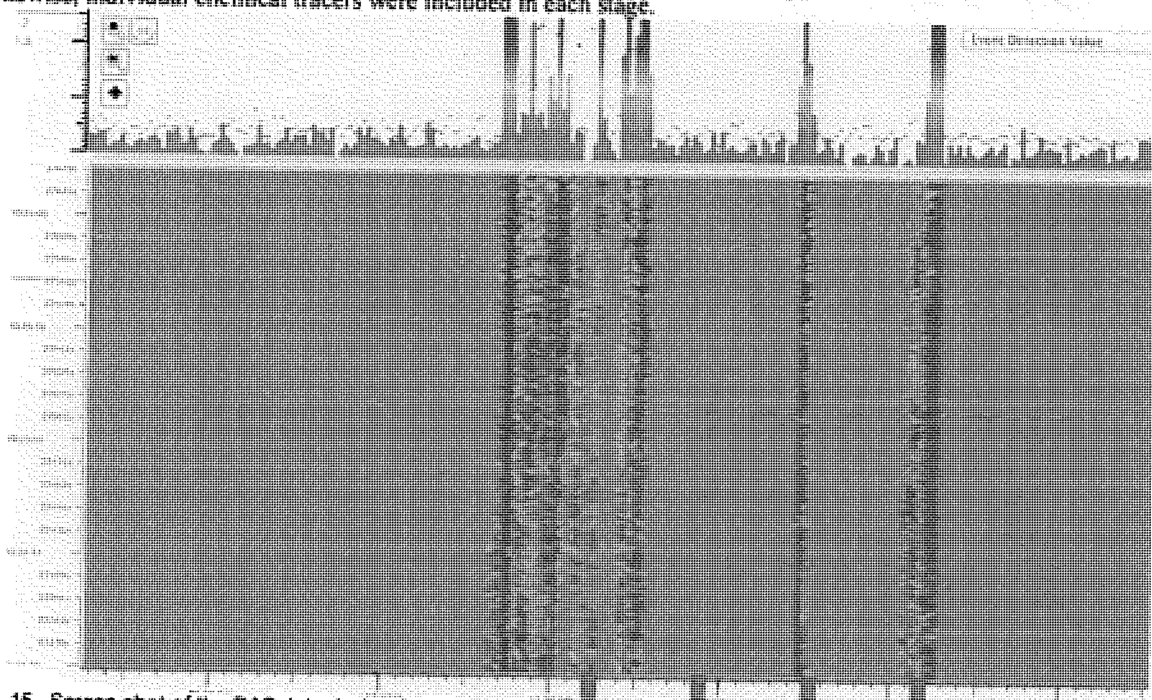

Fig. 15. Screen shot of the DAS data during fracturing operations shows acoustic energy at three out of four valves.

Handling the data generated from the DAS acquisition unit was challenging after the job finished. The acoustic (DAS) data alone exceeded 30 terabytes, and there are currently only a handful of people in the industry capable of handling and processing this kind of information. Hard drives had to be physically moved to the appropriate people rather than being transferred electronically, and a computer had to be specifically built to import and process the data.

Conclusions

As described above, this project involved significant planning and attention to detail. One of the most critical takeaways, therefore, was that ***early planning*** was essential to the success of the project. Looking back, there were very few (significant) problems encountered during the installation and implementation of this comprehensive monitoring system. That being said, there were numerous ***opportunities*** for problems or failures. Although there were many important steps to the planning process, the most important "lesson learned" was that a ***fully integrated*** project team, formed early in the project life, was absolutely critical to the overall success of the project. In addition to involving all necessary disciplines (Completions, Drilling, Reservoir, Geology and Geophysics), it was essential that each team member fully bought into the project and took ownership of their individual responsibilities. To that end, each discipline needed to understand not only what the other disciplines were doing, but why they were doing it. If Drilling didn't understand ***why*** Completions wanted to run fiber optics or sleeves, then it would be easy to come up with reasons why it couldn't be done. If Completions didn't understand why Geophysics wanted both surface and down hole micro seismic data, then it would have been reasonable to develop excuses for why it was impractical. There were numerous opportunities along the way for one particular discipline to forego or eliminate a step to make their job easier, but with a complete understanding of the project objectives, the team continually looked for solutions rather than excuses.

As previously described, one of the most obvious and often overlooked steps in a complicated projects is a pre-job "walk thru" of all system components. One of the most invaluable exercises during the planning and design process was a "stack up" of many of the system components. Representatives from each engineering discipline, as well as field supervisors, foreman and service company representatives met and walked thru all aspects of the proposed installation. Several critical deficiencies became evident during this process, any one of which could have resulted in significant delays if they had not been identified and resolved prior to the actual installation.

Overall, this project was a tremendous success from both an operational and engineering standpoint. It has been shown that numerous technologies, new and traditional, can be combined into a comprehensive monitoring project to provide valuable insight to both completion and production issues. Fiber optic sensing (temperature and acoustic) is an excellent means for monitoring real time downhole fluid flow through individual perforation clusters during frac treatments. Surface microseismic provides meaningful real time information regarding fracture geometry and complexity. Offset bottom hole pressure data, when appropriately collected and analyzed, can provide indications of fracture azimuth, fracture length, and indications of complexity. Radioactive tracers, chemical tracers, production logs and downhole micro-seismic are all useful and provide insightful information when used in conjunction with other technologies.

Through additional and continued analysis of the information collected (and still being collected) from this comprehensive monitoring project, it is anticipated that future similar installations can be used for fracture monitoring to affect real time decisions and improve overall efficiencies. For that to become a reality, there are certainly challenges that need to be overcome. Data integration and data management are significant hurdles. Ultimately, though, it is hoped that this type of monitoring can be used to improve the stimulation process through real time monitoring. Decisions such as decreasing or extending stage volumes, applying diverter techniques or adjusting perforating schemes could potentially improve performance and/or decrease costs. Future installations are currently being planned, and a multi-well fiber optics project using plug and oriented perforating technique is slated for installation later this year. As this technology continues to develop, its usefulness will be better understood.

Acknowledgements

The authors express thanks to Devon Energy and its partner in the subject wells, Cimarex Energy, for permission to share the information contained in this paper, as well as to the members of the project team: Breanne Kennedy (Geophysicist), Chad Kulbeth (Drilling Superintendent), Greg Alexander and Garry Diamond (Completion Foremen), Matt Houston (Geologist), Seyi Harris (Reservoir Engineer), and Jeremy Wells (Scada Specialist). The authors would also like to thank Exiius-Sagerider, i-Tec, Microseismic, Inc. and Schlumberger for their efforts to ensure a successful project.

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New Nouveau Brunswick

FAQs – Hydraulic Fracturing (Fraccing)

What is hydro fracturing?
Hydraulic fracturing, also called "fraccing" is a process used to extract oil and gas. By injecting a fluid comprised of water, sand and a small percentage of chemicals at high pressures, fractures can open up in tight rock formations. This process has been used for decades, can reduce the number of wells needed and can extract gas from rock formations far less permeable than conventional drilling.

What are the chemicals used in hydro fracturing?
The chemicals used in fracing fluid vary from case to case. That is why government is requiring that industry disclose the contents of fracing fluid before any operations go forward, which will then be made public.

By volume, chemical additives typically account for 1% of hydraulic fracturing fluids; the other 99% consist of water and sand. Most of the chemical additives used are also found in common household products. The toxicity of a chemical is determined by the amount and concentration of exposure.

Specific compounds used in a given fracturing operations will vary depending on company preference, source water quality and site-specific characteristics of the target formation.

There are many different options regarding the chemicals used in the process. The safety of these chemicals will be evaluated on a case by case basis.

Will Fraccing deplete New Brunswick's water resources?
The amount of water used during a fraccing procedure varies from well to well. Industry states water volumes range between 250 and 4,000 cubic meters per treatment. It is not currently known how much water a typical shale gas well in NB would require. Hydraulic fracturing at a well pad for horizontal shale gas wells is not a "one shot" process. It is performed in stages. Because the length of the wellbore can exceed one kilometre, it is usually not possible to maintain pressure sufficient to stimulate (frac) the entire length of a lateral in a single stimulation (frac) event. As such, there could be as many as 10-20 stages (fractures) per well.

Each stage requires approximately 4,000 m3 of water to hydraulically fracture using current technologies. Some of this water is returned to surface and can be recycled for use in subsequent stages. It is unknown at this time how many wells could be drilled in the province if sufficient reserves are found through exploration. To put the amount of water used in context, the City of Fredericton consumes on average 23,000m^3 per day, largely for domestic use.

How many times is a well typically fracced?
Generally, shale gas wells are fracced once at the beginning of the process and this can be done in multiple stages in order to ensure sufficient pressure to stimulate the entire length of a lateral. As such, there could be as many as 10-20 stages (fractures) per well.

What happens to the fluid during the process?
A small percentage (between five and 20 per cent) returns to surface with the extracted shale during the initial period of the project. Further amounts are collected over the life of the well. The remainder of the fluid stays in the ground, trapped by the same layers of earth that trapped the natural gas in the first place. Returned fracing fluid will be treated at an appropriate facility as any waste water from an industrial operation routinely is.

What is Gas Migration or Stray Natural Gas Migration?
In improperly operated, poorly constructed or deteriorated wells, natural gas may move from the wellbore. This is called gas migration. Migrating gas can affect water supplies, as well as potentially accumulate inside or next to structures such as residences, businesses and farming operations. This could create a risk of a fire or explosion. Gas migration may become a threat to the health, safety and welfare of the public. The key to avoiding migration is to have stringent industrial guidelines and environmental standards in place.

What is Casing and Cementing?
Casing is a steel pipe inserted in the well to keep gas or oil in the well. It is made out of a series of metal tubes installed in the newly drilled hole. Cementing is the practice of pumping cement down between the casing and the wellbore wall to hold it in place and prevent gas from leaking.

How will you ensure that groundwater is not contaminated by hydraulic fracturing?
The concern for most people is that hydraulic fracturing fluids may contaminate drinking water aquifers by being pushed toward the surface along fault lines and fracture planes. The likelihood of this occurring is remote given the depth at which hydraulic fracturing for shale gas is typically occurring and the distance to drinking water aquifers.

Shale gas deposits currently being exploited in NB are at a depth of approximately 2,000 metres below ground surface. The limit of freshwater aquifers in NB is around 200 m depth. The intervening rock contains multiple layers of tight rock formations which would help to prevent the upward migration of water/fluids to drinking water aquifers.

How will you ensure that groundwater is not contaminated by surface activities?
Reported cases of groundwater contamination associated with shale gas have been linked to casing failures due to poor well construction or over-pressurization of wells (especially older wells with less rigorous standards). Industry uses high-strength steel pipe, which is cemented in place and tested at higher pressures than used during drilling or stimulation. These measures ensure that freshwater resources are protected during the drilling, completion, and production processes.

NB's current regulations and directives set out requirements to set surface casing well below groundwater, cement to surface and pressure test. There are also requirements for intermediate casing (where installed) and production casing. Requirements to repair inadequate cementing jobs and/or abandon wells have also been set out.

Abandoned oil and gas wells in the Stoney Creek area of NB have been thoroughly studied, accounted for and properly decommissioned.

SPE 163827

Breaking Up Is Hard to Do: Creating Hydraulic Fracture Complexity in the Bakken Central Basin

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This paper was prepared for presentation at the SPE Hydraulic Fracturing Technology Conference held in The Woodlands, Texas, USA, 4–6 February 2013.

Abstract

The Bakken drilling boom in North Dakota has seen a frenzy of activity over the past several years as operators sought to hold acreage and create value with the drill bit. This has been particularly true in the Central Basin portion of the Williston Basin where initial wells drilled prior to 2008 were uneconomic. However, advances in completion technology caused such a fundamental shift in economics that the whole Central Basin area of over 2500 square miles has been opened to economic development with ~100 rigs currently drilling in the region.

The most fundamental change in completion design has been the incorporation of "high-intensity" multi-stage fracturing. What makes Bakken completion design fundamentally different from recent shale gas developments has been the widespread use of uncemented liners with external packers in the open-hole lateral in order to create the multi-stage zonal isolation.

As operators have advanced the application of multi-stage completion techniques there has been a wide variety of completion equipment used and stimulation designs that have been pumped. This operator decided to employ a completion design that comprised:

(i) An open-hole "uncemented" liner section;
(ii) Annular zonal isolation created by swell packers;
(iii) The use of "plug and perf" technology to individually open successive zones to stimulation;
(iv) The pumping of slickwater fracture treatment fluids at high rate;
(v) The use of high-quality ceramic proppant to generate the required fracture conductivity.

Production data are presented from 58 wells in which this completion and stimulation design has been conducted, which show that the use of this approach has resulted in well performance that is 25-45% superior to any other Bakken completion technique.

Geology

The Bakken Formation (highlighted in red in **Figure 1**) is located within the Williston Basin, which spans southern Saskatchewan and Manitoba in Canada as well as North Dakota and Montana in the United States. The basin was formed as a subtle down-warping between the Superior Craton to the northeast and the Wyoming Craton to the southwest.[2] The Williston Basin is a gently dipping basin with very little structural deformation, with the exception of a small number of structural features including the Nesson Anticline and the Cedar Creek Anticline, as shown in Figure 1.

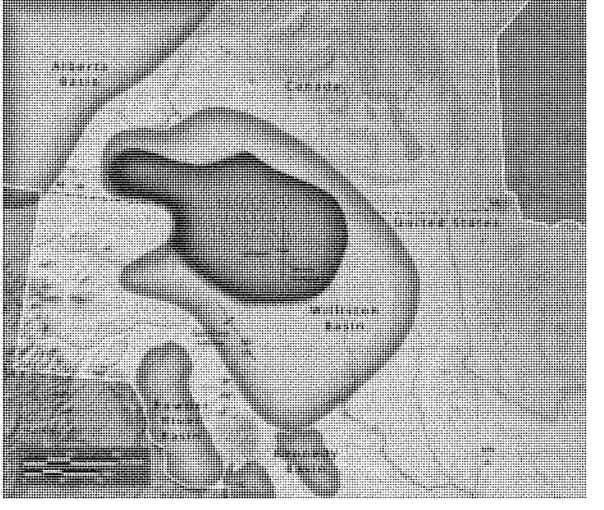


Figure 1—Location of the Williston Basin.[1]

The stratigraphic column (**Figure 2**) shows that the Bakken Formation is Mississippian and Devonian in age. It consists of the Upper, Middle and Lower Members of the formation. The focus of this paper is the Middle Bakken Member. As shown in **Figure 3**, the Bakken does not outcrop at the surface, making it a completely contained petroleum system. The Bakken petroleum system, which includes the underlying Three Forks Formation, has a top seal in the Lodgepole Formation, and a bottom seal in the Nisku Formation. Bakken oil saturations are highest in the deep center of the basin where thermal maturity was greatest, and in stratigraphic traps on the flanks of the basin.

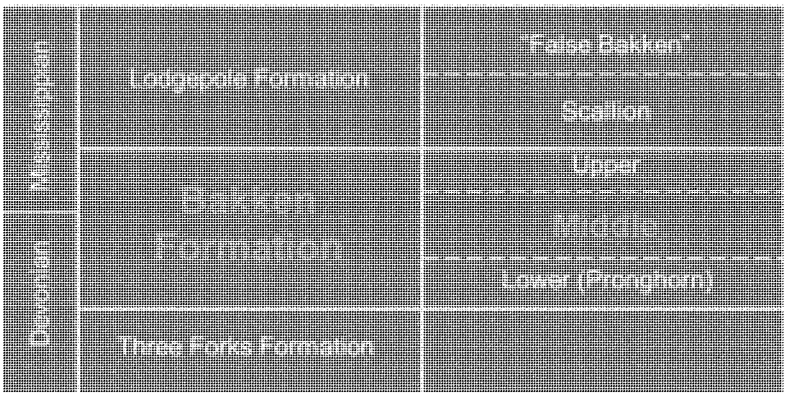


Figure 2—Bakken stratigraphic chart.

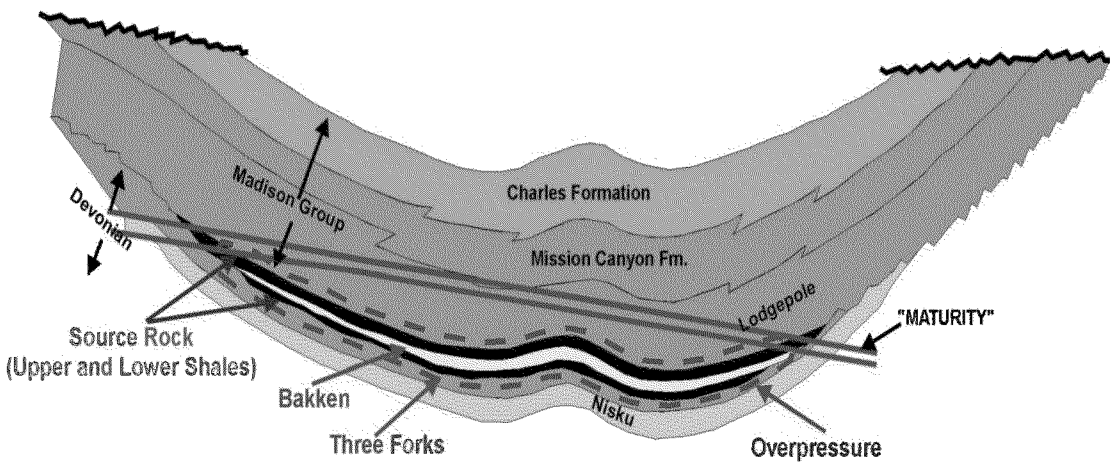


Figure 3—Cross-section of Williston Basin formations.[4]

Figure 4 depicts the Bakken lithofacies using a compensated neutron-density log from the Sanish Field area on the east flank of the basin and core photos of the various lithologic facies. The Upper and Lower Bakken shales are the prolific source rocks for the petroleum system. The Middle Member consists of 5-7 distinct lithofacies that range from silty sandstone on the east flank of the basin to silty dolomite on the west flank of the basin. Porosities in the Middle Member range from 4-10% and permeabilities are generally less than 0.1 md.

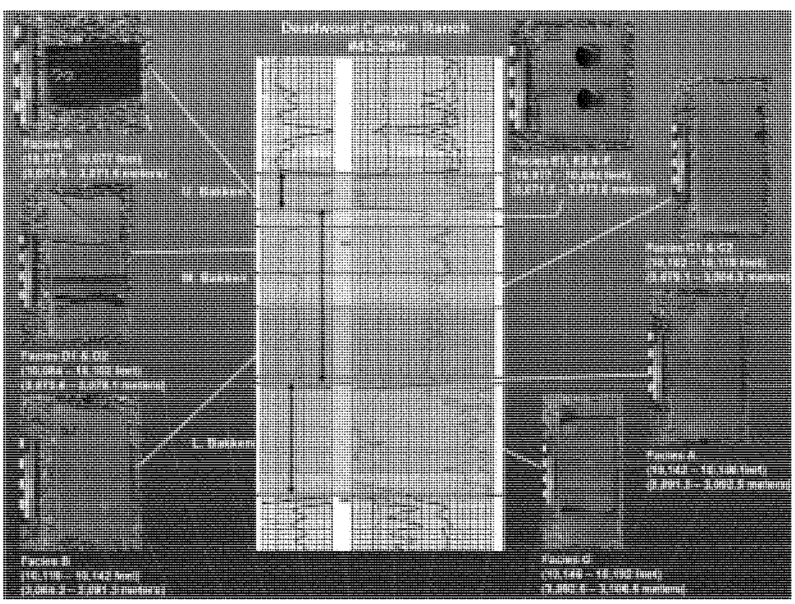


Figure 4—Bakken lithofacies.[5]

Bakken Development History

The first Bakken Formation well came on production in 1953 - just two years after first oil production in North Dakota. Drilling took place along the axis of the Antelope Arch – an anticlinal feature in eastern McKenzie County shown as the first development area in **Figure 5**. Over the next 15 years a total of 42 vertical wells were completed in the Middle Bakken and/or Three Forks formations. Commercial production was dependent on the existence of natural fractures associated with the uplift and could be correlated to the second derivative curvature in the formation.[6]

A second period of Bakken vertical well development occurred between 1970 and 1985 with wells drilled along two other structural features; the much larger Nesson and Billings anticlines. Drilling in the same areas occurred during the third period of development (1986 to 1999), which saw the first use of horizontal wells. These wells were typically completed with pre-perforated liners and generally consisted of single fracture treatments, often incorporating diversion materials in an attempt to generate multiple zones of stimulation.

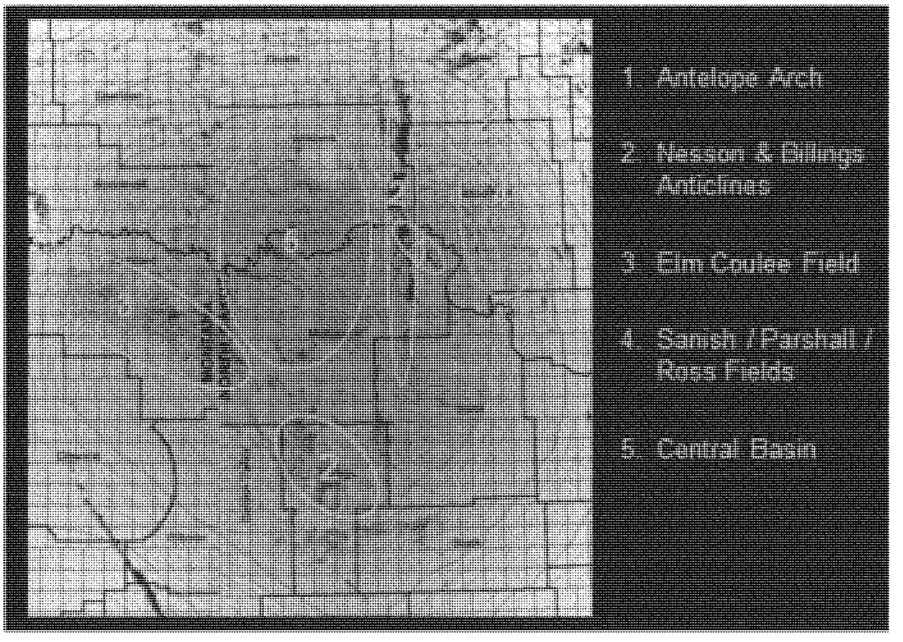


Figure 5—Structural Map with the main development areas in the Williston Basin.

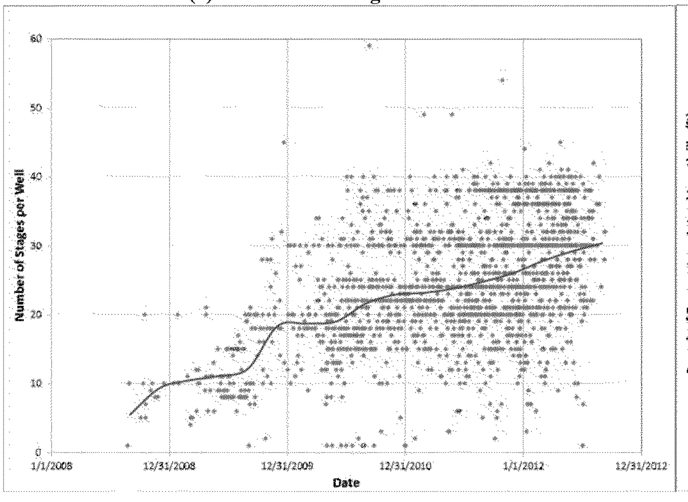
The discovery of a high porosity dolomitized carbonate shoal complex within the Middle Bakken at the Elm Coulee Field in Montana ushered in the next period of development in 2000. Horizontal drilling was used with open-hole single stage completions. The first ten wells all had cemented liners and some flowed after perforating without stimulation. The most significant productivity gains over the early years of Elm Coulee development came with the use of uncemented liners, and the drilling of many wells having multiple horizontal legs. Drilling of the dolomitized shoal facies also crossed the state line into North Dakota as shown in Figure 5.

The broader significance of the Elm Coulee development was the realization that very large volumes of oil had been generated in the Upper and Lower Bakken shales and expulsed into the Middle Bakken and Three Forks zones. This subsequently led in 2006 to the exploration and finding of higher porosity facies in the Ross, Parshall and Sanish fields on the east side of the Nesson Anticline. Well stimulation of these earliest wells typically involved the pumping of a single stage frac of ~2 million pounds of proppant and one million gallons of cross-linked gel. The first multi-stage fracced well was completed in the Parshall Field in 2007 and this technology was rapidly duplicated in other areas of the Williston Basin such that by 2008 the average stage count per well had reached ~10 fracs.[7,8]

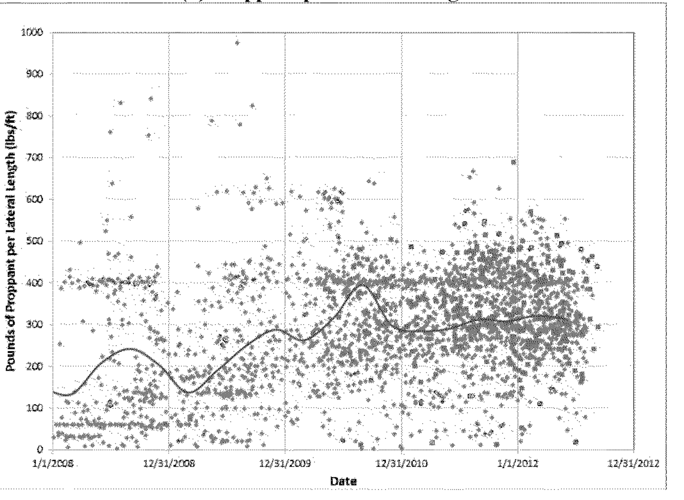
Figure 6 shows several plots with key completion parameters for wells completed since 2008. Hybrid and Cross-Linked gel fracture treatments are depicted for the Central Basin (red) and other areas of the Williston Basin (blue). Slickwater-only designs are shown in green. These data are all compiled from the North Dakota Industrial Commission public database[9].

As can be seen from Figure 6a, the number of stages per well has steadily increased with time from an average of ~10 stages per well in 2008 to an average of ~30 stages per well by mid-2012. Part of this tripling in the number of stages per well is a consequence of the change in North Dakota spacing rules. Prior to 2010, operators could elect to permit either a single section 640-acre well or a dual section 1280-acre well, but in March 2010 the NDIC spaced the remaining extent of the Bakken reservoir on 1280-acre spacing; effectively requiring operators to drill ~9,500 feet laterals in order to hold a Drilling Spacing Unit (DSU). The effect of this can be seen in Figure 6f, where the average lateral length has increased from ~7,500 ft in 2008 to 9,500 ft in mid-2012 as the majority of current drilling is now occurring in 1280-acre spaced DSU's.

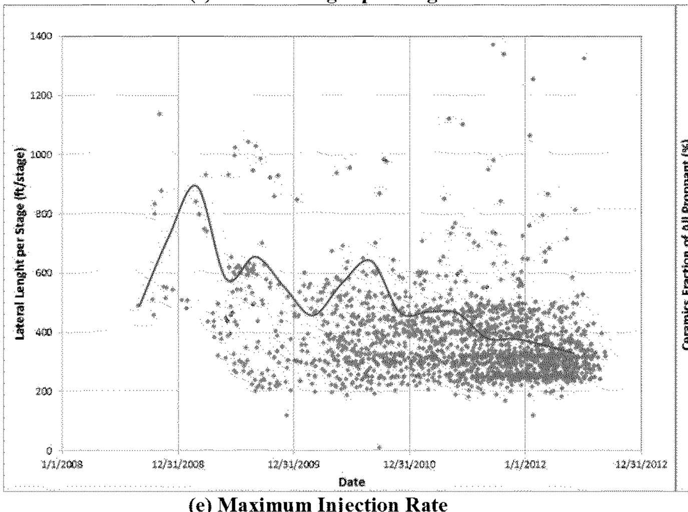
(a) Number of Stages



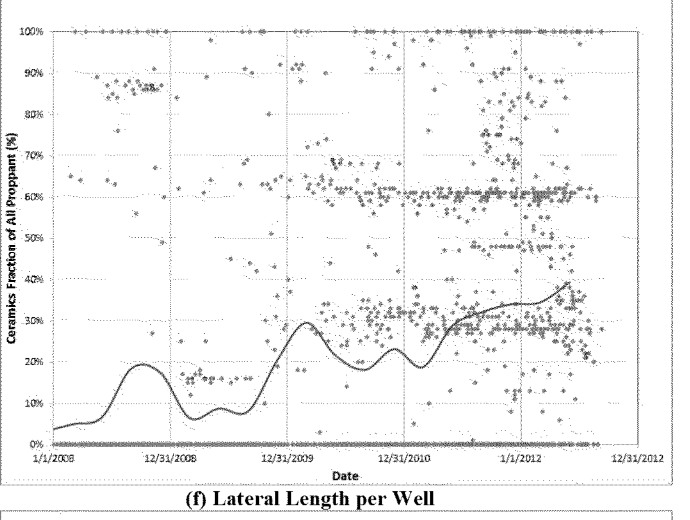
(b) Proppant per Lateral Length



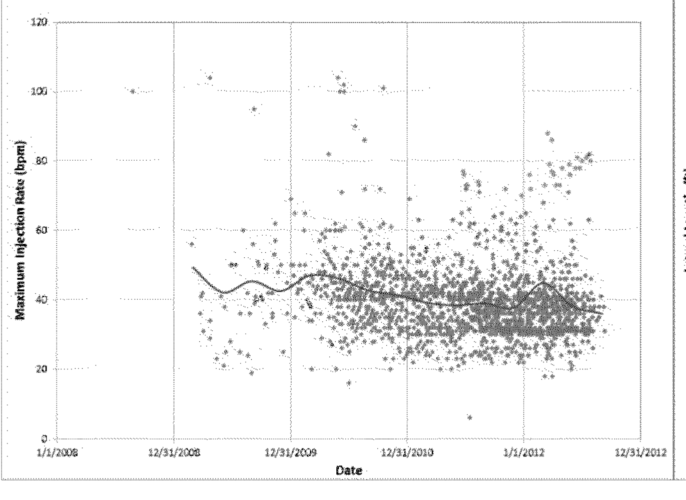
(c) Lateral Length per Stage



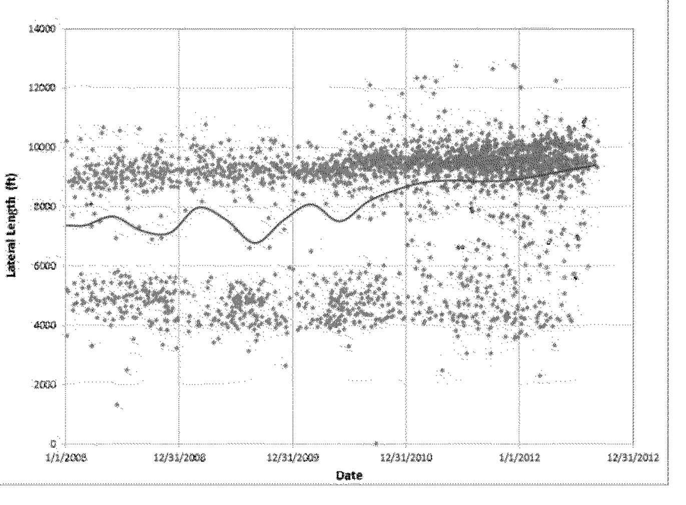
(d) Ceramics Fraction of All Proppant



(e) Maximum Injection Rate



(f) Lateral Length per Well



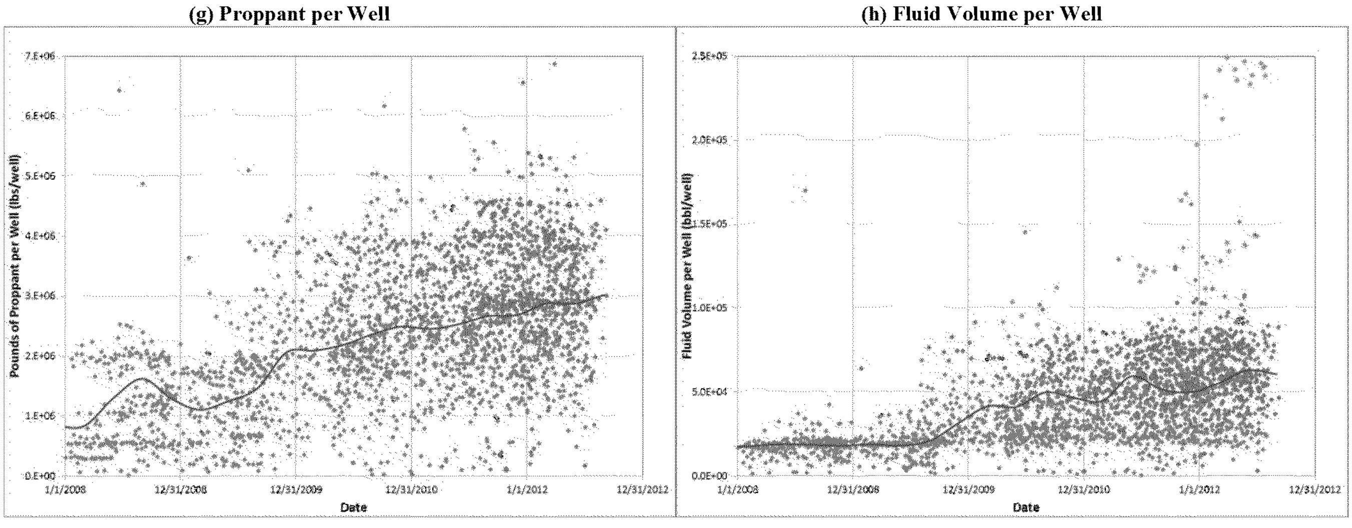


Figure 6—Historical perspective for completion practices for all horizontal wells in the Williston Basin since 2008. Hybrid and Cross-Linked gel fracture treatments are depicted for the Central Basin (red) and other areas of the Williston Basin are shown in blue. Slickwater-only designs are shown in green.

A number of other observations can be made from the data:

(i) The total amount of proppant pumped per well (Figure 6g) has increased significantly with proppant placed per lateral foot increasing from ~100 lbs/ft to more than 300 lbs/ft (see Figure 6b).
(ii) Proppant usage on a per stage basis has been slightly reduced over the last few years from about 150,000 lbs/stage to the current 100,000 lbs of proppant per stage (see Figure 6c).
(iii) In most well stimulation the proppant used has been sand (see Figure 6d). Use of ceramic proppant, however, has increased from a very low base to a current average of about 40% of all proppant placed.
(iv) Injection rate trends have decreased over time with most jobs treated in the range of 30 to 40 bpm (see Figure 6e). A notable exception to this is the slickwater-only stimulations which are typically pumped at rates in excess of 70 bpm.
(v) Treatment volumes per well have gradually increased from 20,000 bbl per well in 2008 to about 60,000 bbl per well in 2012. The slickwater-only stimulations are significantly larger at about 230,000 bbl per well (see Figure 6h).

While the use of uncemented liner completions is standard practice in the Bakken, a number of other key completion design parameters need to be decided by operators on an individual well-by-well basis:

(i) The number of completion stages;
(ii) The method to access the reservoir in each completion stage – Plug and Perf or Sliding Sleeve, or a hybrid completion;
(iii) The use of multiple perforation clusters or multi-port sleeves;
(iv) The type of stimulation; Cross-linked gel, Slickwater or Hybrid;
(v) Fluid volume to be pumped;
(vi) Injection rate;
(vii) Proppant types and amounts;
(viii) The fracture treatment scheduling.

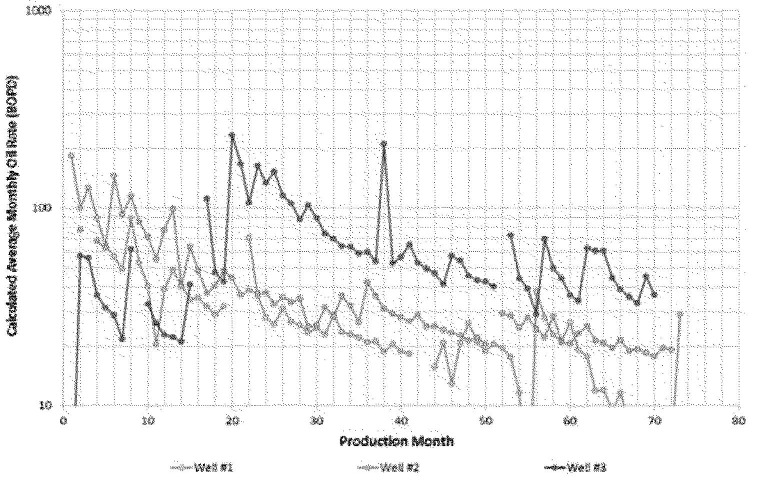


Figure 7—Operator A – Production from the first three wells drilled in the Central Basin in 2006.

Initial Completions in the Central Basin

The first three wells in the Central Basin were drilled and completed in 2006. Completion and stimulation design mirrored common practices of the day using pre-perforated liners and single-stage stimulation treatments incorporating fluid diversion materials. Production results are shown in **Figure** 7; with early production of <100 bopd and average first-year production rates averaging <50 bopd these wells were uneconomic.

After ~18 months of production the liner was pulled from Well #3 and replaced with a 7-stage completion incorporating external packers. Figure 7 shows that after stimulation of all intervals the well's production was increased over five-fold. This paved the way for the drilling of two wells in 2008, which were completed with 20-stage completions. After stimulation of all zones, Wells #4 and #5 produced at 30-day rates of ~600 bopd and as shown in the cumulative production plot in **Figure 8** they had 90-day cumulative production in excess of 40,000 BO (note Well #5 was initially produced from a single stage due to a mechanical problem, but after stimulation of all 20 intervals it had similar production to Well #4). Similar results in the same general area were obtained by a second operator as they moved from 9 to 15 and then 20 stages per well as shown in **Figure 9**. **Figure 10**, the cumulative production plots from the first 13 wells completed by these two operators clearly shows the impact of increasing the number of stages from a single-stage to twenty stages per well with first year cumulative production increasing from <20,000 BO to over 100,000 BO.

A 2010 study[11] utilizing the early results from the Central Basin generated optimization curves for stage count per well for the then-current conditions and incremental production expectations for each stage at that time. For the given economics used in the study (including a WTI oil price of $67.50, $75 & $90 per barrel in years 1, 2, 3+ and service costs existing in 2009) a peak Internal Rate of Return (IRR) was shown to be 25% for a well with 22 stages, while EUR per well leveled off at about 550 Mboe. The study, which was conducted across all Bakken development regions of the Williston Basin, gave correlations of R^2 = 0.91 and 0.96 between 30-day and 90-day cumulative production and forecast EUR's predicted from later historical well production.

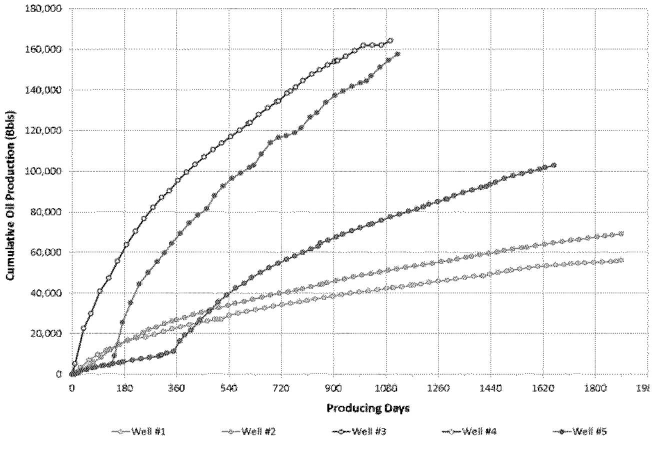


Figure 9—Operator A – Cumulative production versus time from the first five wells drilled in the Central Basin in 2006 & 2008.

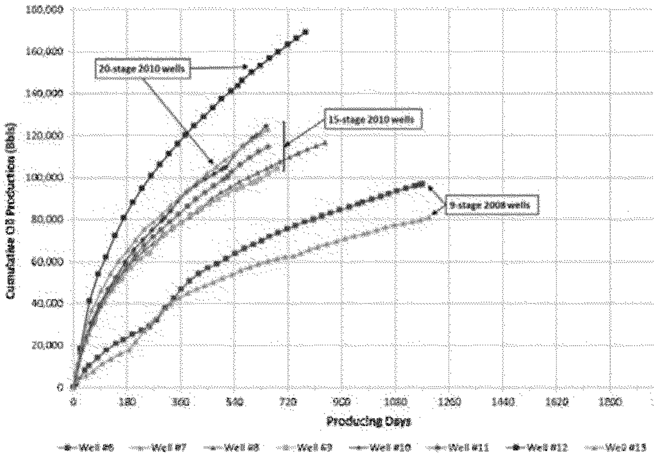


Figure 8—Operator B – Cumulative production versus producing days for Central Basin wells 2008-2010.

Considerations for a Slickwater-Only Design

There are three critical completion and fracture stimulation design parameters affecting production from an unconventional resource formation:[12-14]

(i) Stimulated Reservoir Volume (SRV),
(ii) Fracture contact area within the SRV, and
(iii) Fracture conductivity.

SRV is a measure of the extent of the reservoir coverage by the induced hydraulic fracture system and will define the total hydrocarbon in place contained within the stimulated volume. However, this does not quantify the degree of coverage, or density of hydraulic fractures, within the covered volume. Since early- and middle-time oil and gas flow will be controlled by the created fracture contact area and fracture conductivity both of these parameters are critical design parameters.

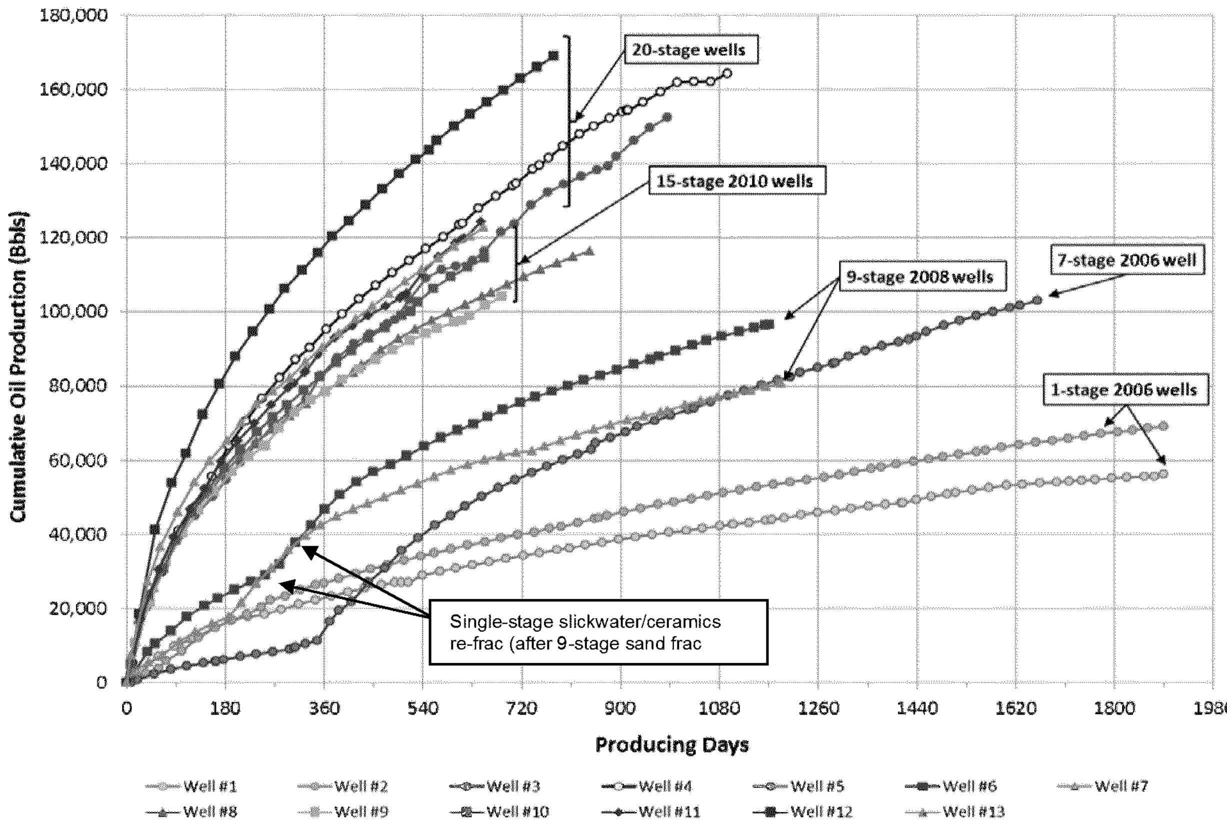


Figure 10—Impact on cumulative production for Operator A and B initial wells (2006-2010). Note Well #5 production is time-offset until the stimulation of all zones was carried out.

Figure 11 shows the ability to create complexity and reservoir contact area through a fracture system depends on the well completion and the fracture treatment design. Low rate, high viscosity fracture fluids injected into an unperforated wellbore are likely to activate only a few pre-existing natural fractures which act as points of weakness. Alternatively, in the absence of natural fractures, basic rock mechanics dictates that a longitudinal fracture will be created axially along the wellbore. In contrast, a similar fluid system injected into a perforation cluster is likely to initiate new artificial fractures – as well as opening existing natural fractures. However, due to viscosity effects and stress shadowing it is likely that only a few dominant fractures will be extended into the reservoir. By contrast, as schematically shown in Figure 11, if the injection fluid is changed to a high-rate, low viscosity fluid such as slickwater there is both the likelihood of multiple fracture initiation points and the stimulation of a much more complex set of natural fractures. The ability to create more complexity with slickwater was first documented in re-fracture treatments in the Barnett Shale, where original fractures completed with gel showed both lower contact area as observed with micro-seismic mapping and lower production response than the slickwater re-fracs[15]. The ability of the Plug and Perf technique to act as points of fracture initiation has been documented in the field using micro-seismic mapping.[16,17]

As described in **Figure 12**, the fracture geometry created in a low-rate gel treatment in the absence of new fracture initiation points from perforations is most likely in the form of a single or a few dominant fractures having a fracture width several proppant grains wide.[18,19] In contrast, the fracture geometry for a high-rate slickwater treatment contains significantly more contact area, as the low-viscosity fluid may create more fractures in the preferred fracture plane, but possibly also penetrate into pre-existing weaknesses or natural fractures present in the rock outside this preferred fracture plane. Conservation of mass would suggest that a 10,000 bbl slickwater treatment, with perhaps 90% fluid efficiency and creating fractures of only 0.1" width, has the capacity to generate several million square feet of contact area within the Stimulated Reservoir Volume. In such a scenario, as proppant is distributed over a fracture network with significantly larger surface area, the proppant distribution per fracture is significantly less, and most likely only a partial monolayer. Due to the high complexity of the natural fracture system in the Bakken, and despite the larger amount of proppant which settles in the fractures due to poor proppant transport, the creation of partial proppant monolayers is probably more the rule than the exception in these treatments. Use of small-mesh proppant and stronger proppant helps transport these proppants deeper in the fracture system and provide more strength to provide the required fractured conductivity to sustain long-term enhanced productivity.

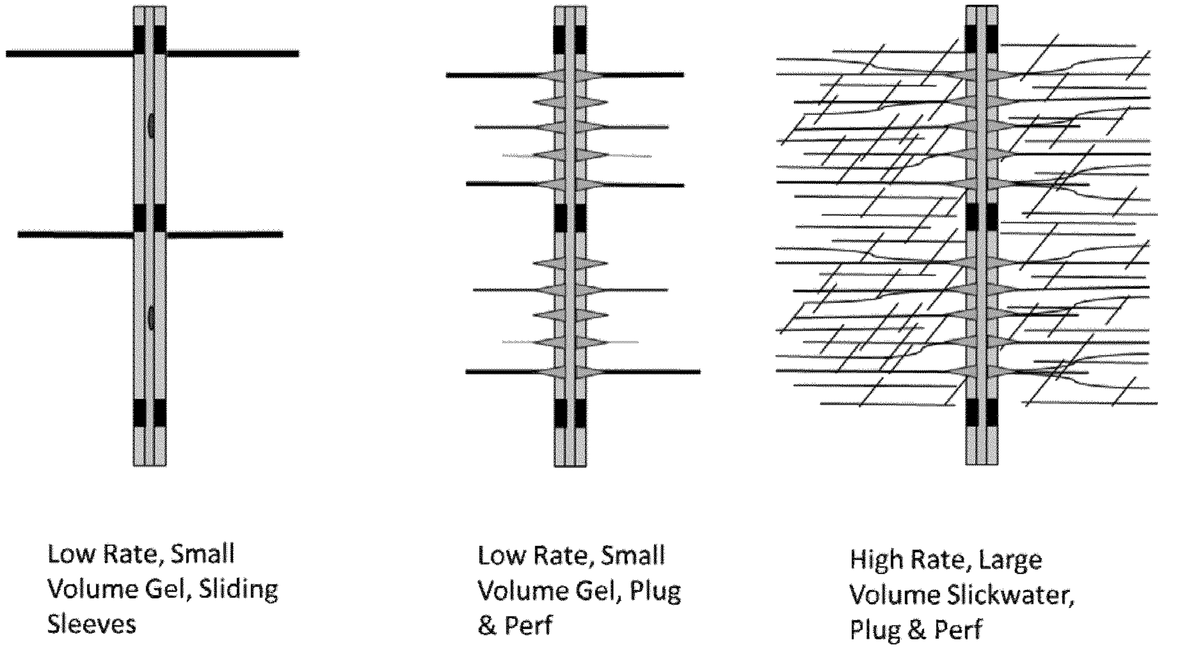


Figure 11—The ability to create complexity and reservoir contact area through a fracture system depends on the well completion and the fracture treatment design.

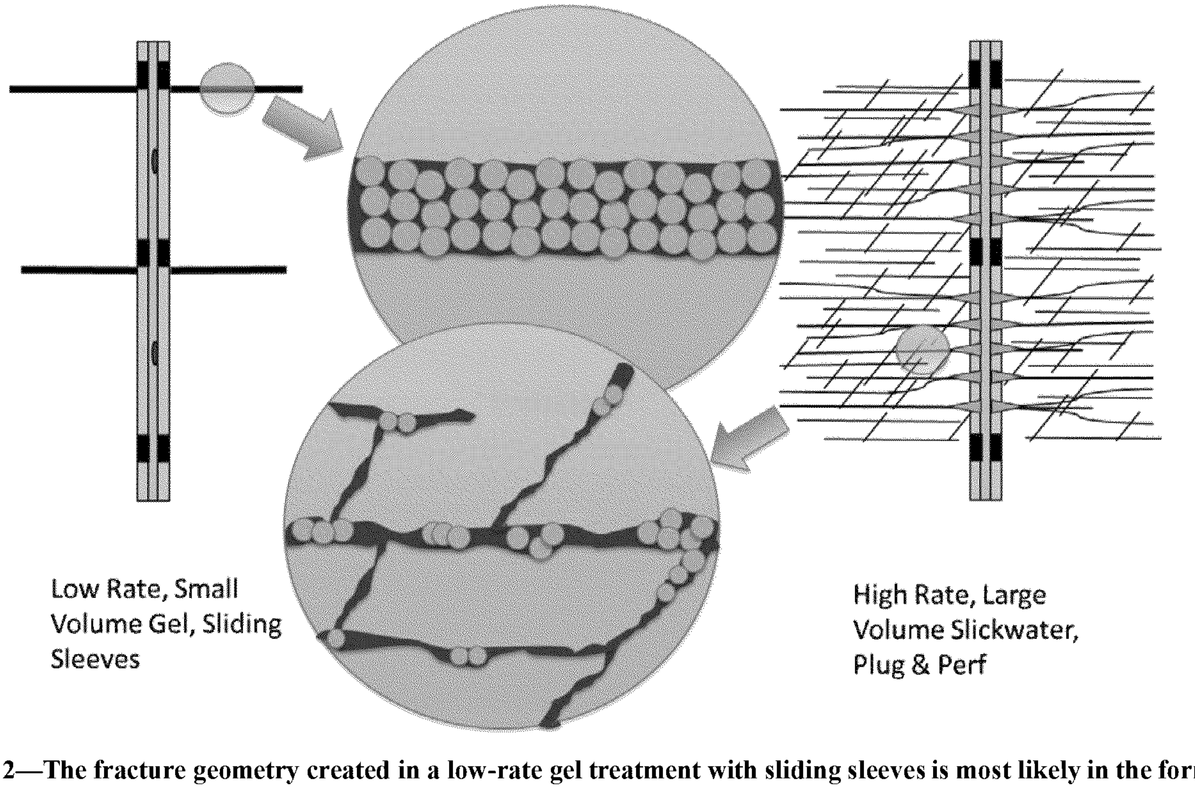


Figure 12—The fracture geometry created in a low-rate gel treatment with sliding sleeves is most likely in the form of a single dominant fracture, whereas the fracture system created with a slickwater-only treatment through perforations results in significantly more surface area.

Completion design parameters thus decided by the operator in order to maximize fracture contact area and complexity included:

(i) Use of multiple limited-entry perforation clusters as a source of fracture initiation locations.
(ii) To maximize fracture complexity through only pumping low-viscosity slickwater fluid.
(iii) To pump at maximum rates as permitted by existing casing and liner designs (P-110 grade pipe with a 7" long-string and 4½" liner). This meant that friction effects limited injection rates to 70-80 bpm.

Stimulation design parameters to provide sufficient fracture conductivity included:

(i) To define proppants which had the capacity to provide sufficient conductivity in partial monolayer or low concentration loadings of < 1 lb/ft^2.
(ii) To setup a test program for all potential proppants at actual stress and temperature conditions as exist in the formation through running a standardized long-term (50 hour) proppant conductivity test at 9,000 psi total stress and 250°F. This eliminated the potential for using sand proppants and dictated the need to run premium ceramic proppant in order to maintain effective conductivity.
(iii) The use of surfactant and micro-emulsion additives to aid in the initial cleanup of the fracture face and propped fracture.

Slickwater Implementation

Bakken frac fleets are typically comprised of 6 to 8 pumping units since they were only required to pump at rates of 20 to 50 bpm (as shown in Figure 6). An 8-pump frac fleet injecting at 40 bpm and 7,500 psi has about 50% excess/standby pumping capacity. In order to inject slickwater fracs at up to 80 bpm and 9,500 psi it was required to have a minimum of 10 pumping units (12 with standby units) in the frac fleet.

While such a frac fleet is standard (and often significantly larger) in most of the gas shale areas which utilize slickwater fracturing, this was not standard in the North Dakota pumping service industry. For this reason, and also in part because of the lack of pumping service capacity in the basin during late 2010 and 2011, the operator developed its own capability to pump high-rate slickwater fracs through the launch of a service company with these capabilities. **Figure 13** shows these pumping services rigged up on location with 10 pumps in-line ready to pump a 35-stage stimulation on a well with a slickwater-only design.

Figure 13—Bakken service company crew rigged-up for slickwater stimulation.

The actual treating schedule for the slickwater fracs has undergone some changes over the past three years in order to get a design that can be routinely placed with minimal risk of screenout. While this may seem trivial given the large amount of slickwater fraccing that has gone on in gas shale formations, it should be noted that most of these stimulations occur in completions which are fully cemented. There is a significant difference with an uncemented liner where part of the slurry flow is travelling in the liner/open-hole annulus. Depending on the amount of flow in the annulus this has differing propensity to screenoff and can dramatically increase treating pressures. Due to the North Dakota ruling on 1280-acre spacing units, most new horizontal wells in the Central Basin are drilled in a north-south orientation. Given that the preferred fracture plane is oriented at N50°E in most of the Williston Basin, the fracture plane is therefore oriented at an oblique angle with the well orientation. This oblique orientation generally results in the most near-wellbore tortuosity challenges of any possible wellbore-to-fracture orientation[10], thus providing an extra possible complication to the implementation of fracture treatments in general and slickwater treatments in particular. Recognizing this in real-time, and having a well-defined plan to deal with pressure increases is therefore key to risk mitigation and routinely placing slickwater fracs in short, uncemented completion intervals.

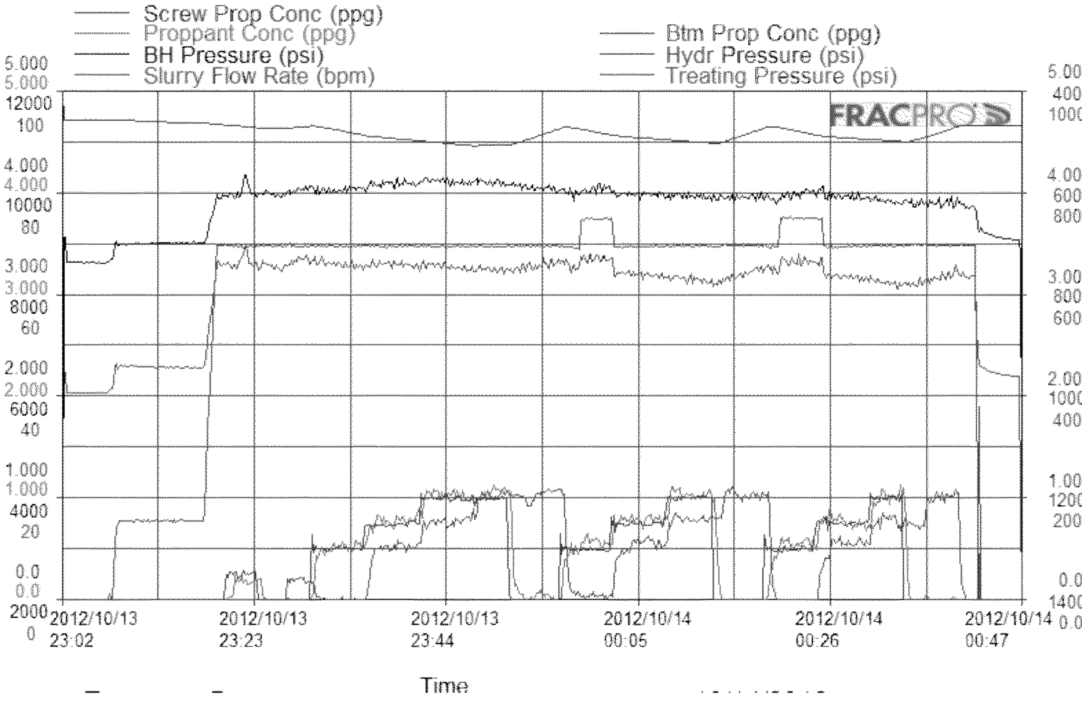


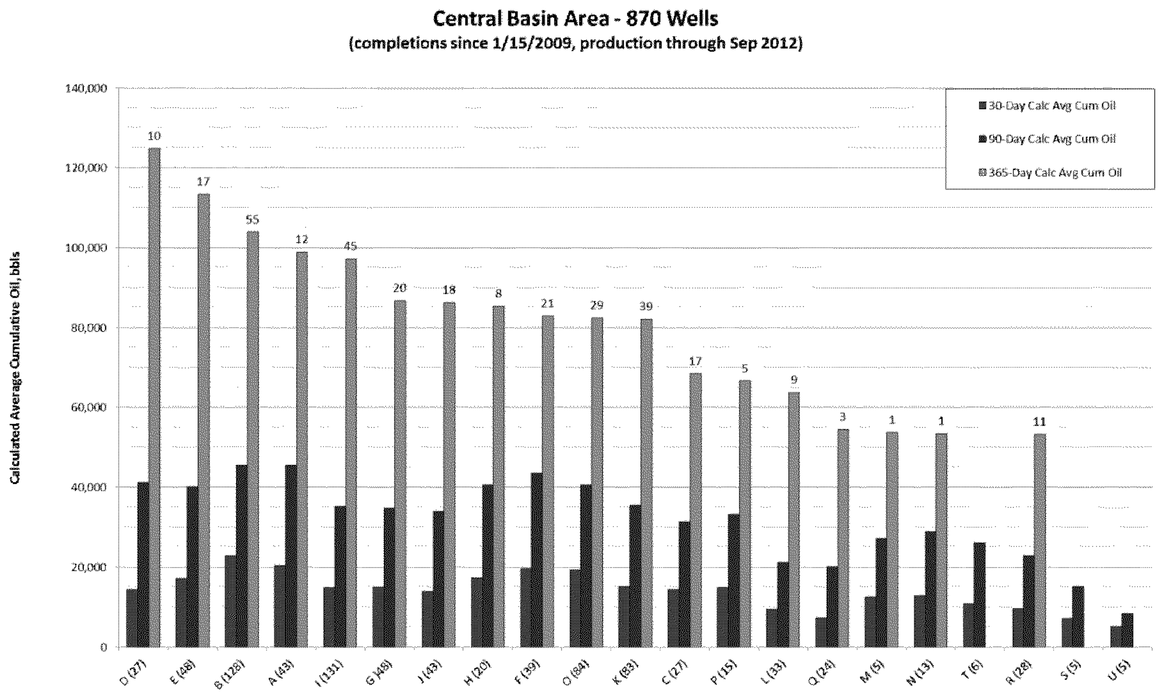
Figure 14—Example Middle Bakken slickwater fracture treatment plot.

Figure 14 is a typical treatment plot from a job in which no pressure anomalies due to annular flow effects or near-wellbore effects occurred. As shown, the current design includes limiting proppant ramps to only 1 ppa of proppant concentration and the use of 500 bbl sweep stages between ramps. We see varying levels of potential proppant placement problems in Bakken slickwater-only treatments, and we have evolved approaches to deal with these events, thus maximizing proppant placement while minimizing screen-outs. With more than 1,100 slickwater treatments performed in 2012 through the month of October, screen-outs have only occurred four times – and all in jobs pumped at the very beginning of the year, and not during the last 900 stages.

Production Results

The Bakken is an over-pressured reservoir with pore pressure gradients in excess of 0.75 psi/ft in the deepest parts of the basin. As a consequence, post-frac flowback fluid volumes provide an almost immediate indication of stimulation effectiveness. It is not unusual to start cutting oil within the first 24 hours of flowback as formation fluids are produced in addition to the fracturing fluid.

Maximum production rates are typically generated during the plug or seat drillout phase since reservoir pressure is still charged by the injection of stimulation fluids. However, variation in drill-out procedures between operators does not make the initial flow data a suitable metric for direct comparison between different completion designs. Similarly, differences in flowback procedures and choke settings in the early-time operating philosophy of different operators can result in significant variation in 30-day cumulative production data.



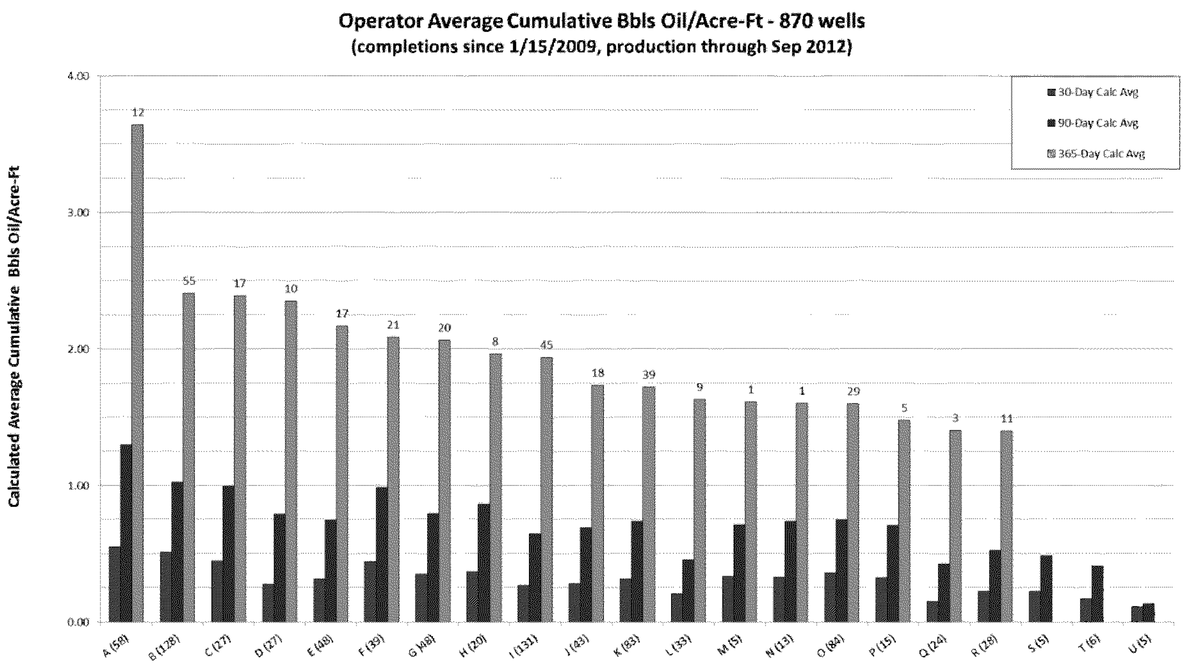


Figure 15—30, 90 and 365 day production response (absolute production on top; production response as normalized by reservoir thickness and acreage per well on bottom), as sorted by operator, for all wells in the Central Basin. Well count for total # wells per operator shown next to operator label, well count for # wells with 365 days production given above that bar.

The 2010 study of the Bakken formation had demonstrated an R^2 correlation of 0.96 between 90-day production responses to forecast EUR's predicted from later historical production.[10] Intuitively this also seemed an appropriate time period for defining a quantitative production metric since it is beyond the period of initial high-drawdown in which different operating practices will be a significant driver of results.

As of September 2012, there exist a total of 870 Central Basin wells in the NDIC public database which have at least one month of production data. **Figure 15** shows a bar chart of 30, 90, and 365 day data for all companies having at least five wells in the database. As seen in the data there is a wide range of performance. Normalizing the data to take into account whether the well is drilled in a 640-acre or 1280-acre DSU and for variations in the gross thickness of the Middle Bakken interval is shown in the lower plot of Figure 15. This shows that the Plug and Perf completion design with Slickwater & Ceramic Proppant fracs has over 25% better normalized cumulative production after 90-days of production when compared to any other completion and stimulation design; and over 45% better than any other design after 365-days of production.

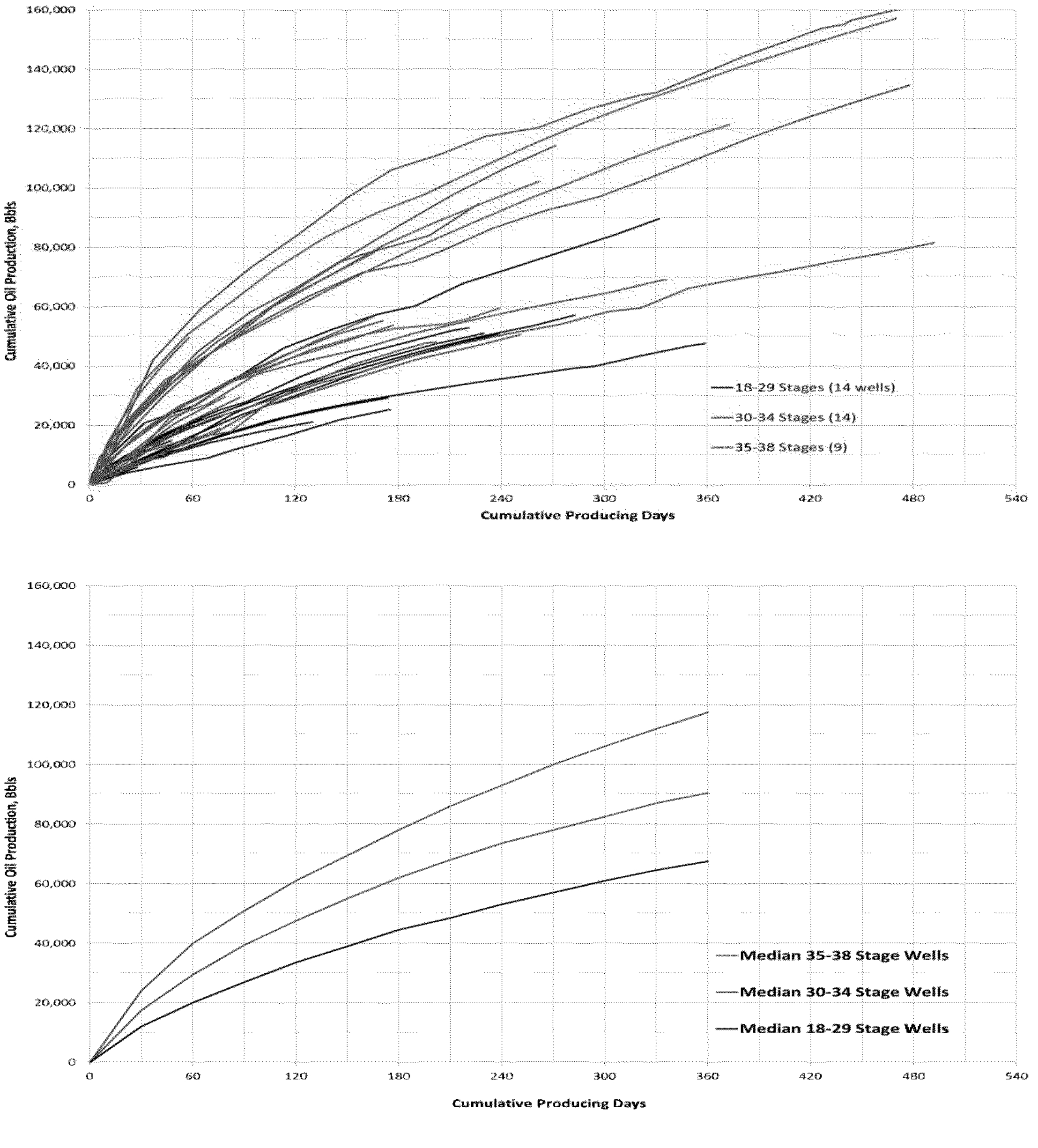
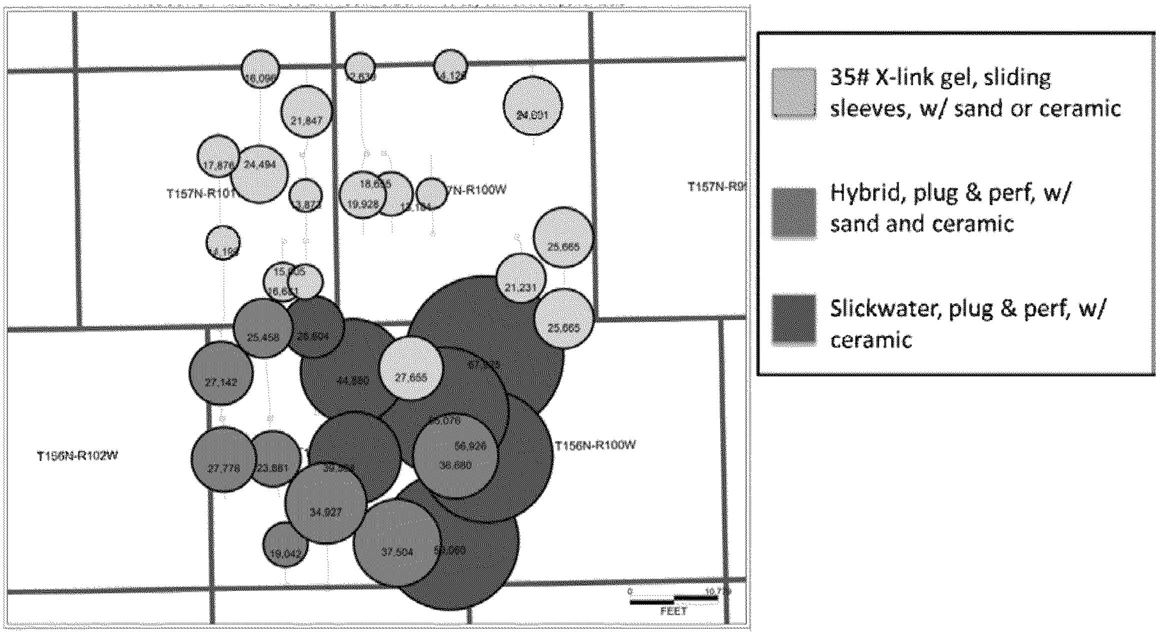


Figure 16—Impact on cumulative production response for subdivision of 10,000-ft lateral horizontal wells into more plug&perf stages. A total of 37 wells located in or surrounding Township 156N-R101W in Williams County (All 1280-acre wells completed after 1/1/2009).

One of the perennial issues clung to by the nay-sayers of a high level of stimulation work is that the increased initial performance is merely rate acceleration and that after a few years of production the higher level of decline will ultimately result in equivalent cumulative production and similar EUR's. The vast majority of Central Basin wells are too early in their productive life to argue this point conclusively. However, Figure 15 shows that the differential benefit of slickwater completions is increasing with time during the first 365-days of production. Most notably, poorer performing completions after 30 and 90 days of production are still the lowest performing completions after 365 days of production. What is more, many of these poorer performing wells after the first year of production are experiencing similar decline rates to the higher performing wells.

While the above analysis was performed across the whole Central Basin it should be expected that geological variations could have a significant impact on the results. We have found that local correlations are more indicative and quantitive of the impact of completion parameters. An example is shown in **Figure 16** where 37 wells are compared, all within or surrounding Township 156N-R101W in Williams County. All of these wells are over 9,000 ft long laterals in 1280-acre DSU's with 26 to 35 stages and roughly 100,000 lbs of proppant per stage. But the similarities end there. The 37 wells provide a localized comparison of the production performance from the three main broad completion approaches currently employed in the Bakken:



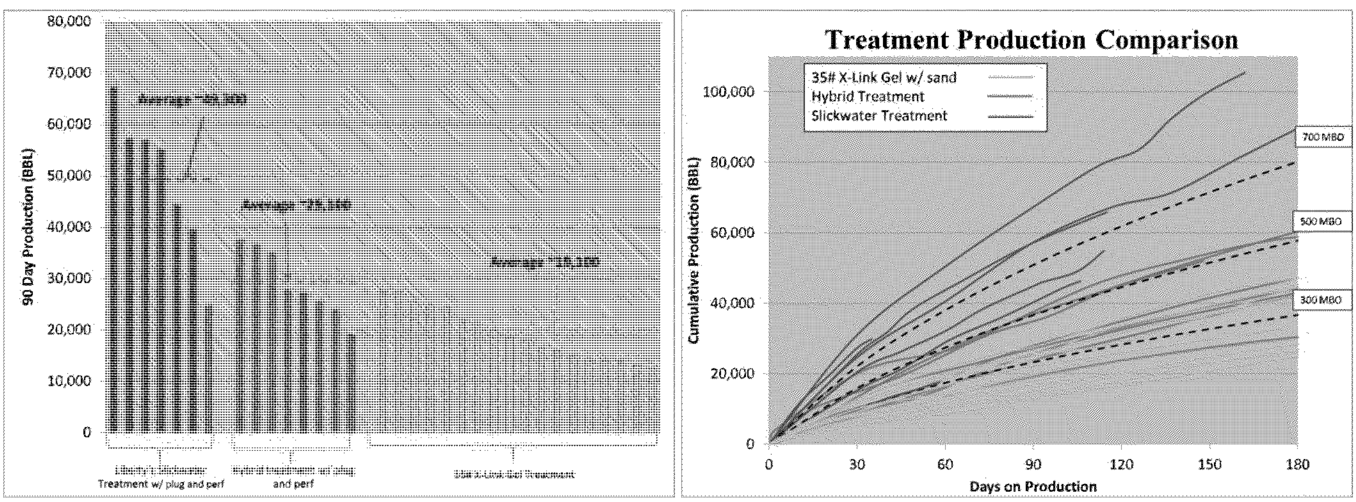


Figure 17—90-day production comparison for gel, hybrid and slickwater treatments in or surrounding Township 156N-R101W in Williams County.

(i) Sliding Sleeves with cross-linked gel fracture treatments placing either sand or ceramic proppant;
(ii) Plug and Perf with hybrid slickwater and cross-linked gel placing sand and (mostly) ceramic proppant; and,
(iii) Plug and Perf with high-rate slickwater placing ceramic proppant.

Figure 17 shows a 90-day production bubble-plot with three different colors illustrating the dramatic difference in performance of these approaches in the same neighborhood.

Figure 18 lists data on the specific designs. As shown in Figure 17, the three different completion and stimulation designs have a large variation in 90-day cumulative production, with averages ranging from 19,100 BO, 28,800 BO to 49,300 BO. Clearly, with wellhead commodity prices of over $80 per barrel the increased time and costs of the Plug and Perf completion design with slickwater fracturing is highly economic.

Treatment type	Avg. Number of stages	Avg. Stage spacing	Avg. Fluid volume per lateral foot	Avg. Proppant/sand weight per lateral foot
Slickwater	35	277 ft	25.3 bbl/ft	412 lb/ft
Hybrid	26	368 ft	7.6 bbl/ft	282 lb/ft
Cross-link	29	339 ft	6.6 bbl/ft	383 lb/ft

Figure 18—Completion differences for the production comparison in or surrounding Township 156N-R101W in Williams County.

Conclusions

Multi-stage hydraulic fracturing of horizontal wells has had a transformative effect on the Central Basin portion of the Williston Basin Bakken. Horizontal wells which were uneconomic with single-stage completions using diversion technology fracture treatments have become wildly economic with multi-stage mechanical isolation.

While drilling procedures and casing plans have become standardized across the industry there exists a wide variation in the type of completion and stimulation procedures being employed by different operators.

The operator has now completed over 70 wells with the Plug and Perf completion design with slickwater fracturing. Initial results presented from 58 wells contained in the NDIC public database show this is generating far superior production results that pay out additional service costs in less than 90 days compared to other completion and stimulation designs.

There is no reason why the completion and stimulation design presented here cannot be applied to the Three Forks formation – and we have recently successfully applied this although production results have not yet been publicly released.

There has been such a drive over the past two years to drill the first well in each DSU in order to HBP the acreage that industry has had little time to further optimize completion practices. More thorough evaluation of the public production data is on-going and we anticipate that as best practices are shared the industry will move towards a consensus completion and stimulation plan when infill drilling is carried out.

Acknowledgements

The authors would like to thank their co-workers at Liberty Resources and Liberty Oilfield Services who helped with the preparation and review of this paper.

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To: Yohannes, Lia[Yohannes.Lia@epa.gov]
From: Ridley, Caroline
Sent: Thur 2/19/2015 5:58:23 PM
Subject: RE: Request: Permission to use an image

Hi, Lia,

Ex. 5

C

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Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 Ex. 6

From: Ridley, Caroline
Sent: Monday, February 09, 2015 11:11 AM
To: Yohannes, Lia
Subject: RE: Request: Permission to use an image

Ex. 5

Thanks!!!!

Caroline
~~~~~~

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Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 Ex. 6

From: Yohannes, Lia
Sent: Monday, February 09, 2015 11:04 AM
To: Ridley, Caroline
Subject: RE: Request: Permission to use an image

Ex. 5

Liabeth Yohannes

Student Services Contractor

Office of Research and Development

U.S. Environmental Protection Agency

e: Yohannes.lia@epa.gov

p: 202.564.6755

From: Ridley, Caroline
Sent: Monday, February 09, 2015 10:35 AM
To: Yohannes, Lia
Subject: RE: Request: Permission to use an image
~~~~~~

Ex. 5

Caroline

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Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 Ex. 6

From: Yohannes, Lia
Sent: Monday, February 09, 2015 10:30 AM
To: Ridley, Caroline
Subject: RE: Request: Permission to use an image

Ex. 5
~~~~~~

Ex. 5

Lia

Liabeth Yohannes

Student Services Contractor

Office of Research and Development

U.S. Environmental Protection Agency

e: Yohannes.lia@epa.gov

p: 202.564.6755

From: Ridley, Caroline
Sent: Monday, February 09, 2015 10:24 AM
To: Yohannes, Lia
Subject: RE: Request: Permission to use an image

Ex. 5 -Caroline

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Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 Ex. 6
~~~~~~

From: Yohannes, Lia
Sent: Monday, February 09, 2015 9:54 AM
To: Ridley, Caroline
Subject: FW: Request: Permission to use an image

Hi Caroline,

Ex. 5

Lia

Liabeth Yohannes

Student Services Contractor

Office of Research and Development

U.S. Environmental Protection Agency

e: Yohannes.lia@epa.gov

p: 202.564.6755

From: Yohannes, Lia
Sent: Monday, February 09, 2015 9:51 AM
To: 'Crane, April'
Subject: RE: Request: Permission to use an image

Hi April,

Ex. 5

Best,

Lia

Liabeth Yohannes

Student Services Contractor

Office of Research and Development

U.S. Environmental Protection Agency

e: Yohannes.lia@epa.gov

p: 202.564.6755

From: Crane, April Ex. 4
Sent: Monday, February 09, 2015 9:49 AM
To: Yohannes, Lia
Subject: RE: Request: Permission to use an image

Hi Lia – I looked through both our US photo library and reached out to my peers in Canada; unfortunately, we don't have the types of images you are looking for. I'm sincerely sorry.

April

From: Yohannes, Lia [mailto:Yohannes.Lia@epa.gov]
Sent: Thursday, February 05, 2015 12:11 PM
To: Crane, April
Subject: RE: Request: Permission to use an image

Hi April,

Thank you for your response. We were especially interested in this photo because we would like to show a well site before and after production begins, and we have the before image for this site. However, we would still be very interested in a replacement image of a well site in production. Do you have any before and after photos of the same site? The photo can be from any state.

Thanks again for your help.

Best,

Lia

Liabeth Yohannes

Student Services Contractor

Office of Research and Development

U.S. Environmental Protection Agency

e: Yohannes.lia@epa.gov

p: 202.564.6755

From: Crane, April Ex. 4
Sent: Thursday, February 05, 2015 1:05 PM
To: Yohannes, Lia
Subject: RE: Request: Permission to use an image

Hi Lia,

Thank you for getting in touch. Unfortunately, we have little information on this image. If it is indeed Fortuna, that dates back more than five year. What I can do is look through our photo library and see if I can find a suitable replacement image that is more current and that I can confirm we have usage rights over. Does it have to be Pennsylvania?

Thanks,

April

April Crane
Director, US Communications I Talisman Energy USA
e: acrane(Ex. 4] o: 832.663.3883 Ex. 6

From: Yohannes, Lia [mailto:Yohannes.Lia@epa.gov]
Sent: Wednesday, February 04, 2015 2:01 PM
To: Calgary, TLM
Subject: Request: Permission to use an image

Hi,

My name is Lia Yohannes - I'm a scientist at EPA helping to develop a report on the impacts of hydraulic fracturing on drinking water. I obtained a copy of an image (below) of a well site taken by Fortuna Energy in Troy, PA from the New York Dept. of Environmental Conservation's Environmental Impact Statement (SGEIS) Report. We are interested in reprinting the photo to provide a visual of what a well site looks like once production begins.

Do you have any information about who took the photo, whether he/she would be willing to grant permission to use it, and the availability of a high-resolution image?

Thanks for your consideration. Feel free to email a response or give me a call in my office (number below).

Best,

Lia

Liabeth Yohannes

Student Services Contractor

Office of Research and Development

U.S. Environmental Protection Agency

e: Yohannes.lia@epa.gov

p: 202.564.6755

To: Jonathan Koplos Ex. 4 Frithsen, Jeff[Frithsen.Jeff@epa.gov]
Cc: Anna Weber Ex. 4
From: Ridley, Caroline
Sent: Thur 2/19/2015 12:01:14 PM
Subject: FW: Chapter 7

Ex. 5

~~~~~~

Caroline E. Ridley, PhD

Ecologist

US Environmental Protection Agency

Office of Research and Development

National Center for Environmental Assessment

Office: (703) 347-8506 Ex. 6

From: Jim Weaver Ex. 6
Sent: Wednesday, February 18, 2015 10:18 PM
To: Ridley, Caroline; Cluff, Maryam; Lowrance, Richard; Weaver, Jim
Subject: Chapter 7

Ex. 5

I'm sending this from my home email, because the EPA remote access email appears not to be working at the moment.

-Jim
~~~~~~

To: Maddox, Donald[Maddox.Donald@epa.gov]; Ben Husch[Ex. 4] Melanie Condon[Ex. 4]; Judy Sheahan[Ex. 4]; Carolyn Berndt (Ex. 4
Cc: Hanson, Andrew[Hanson.Andrew@epa.gov]; Cook-Shyovitz, Becky[Cook-Shyovitz.Becky@epa.gov]; Richardson, Elena[Richardson.Elena@epa.gov]; Hannon, Arnita[Hannon.Arnita@epa.gov]; Rupp, Mark[Rupp.Mark@epa.gov]
From: Julie Ufner
Sent: Tue 5/12/2015 11:59:29 PM
Subject: RE: Meeting Request

Hi Don--

The 19th would work better for me.

The 18th I will likely be unreachable, I won't be in a place where I can get cell phone reception
The 20th is difficult since NACo's WIR conference starts and I have several meetings going on. I will be busy 1:30 EDT--onward (7:30 a.m. Hawaii time).

Julie Ufner
NACo

-----Original Message-----
From: Maddox, Donald [mailto:Maddox.Donald@epa.gov]
Sent: Tuesday, May 12, 2015 3:47 PM
To: Julie Ufner; Ben Husch; Melanie Condon; Judy Sheahan; Carolyn Berndt Ex. 4
Cc: Hanson, Andrew; Cook-Shyovitz, Becky; Richardson, Elena; Hannon, Arnita; Rupp, Mark
Subject: RE: Meeting Request

Let me apologize up front for being a day late on these options, but listed below is what we can pull together on the 18th, 19th, and 20th.

18th: 4:30 pm 5:00 pm

19th: 4:00 pm, 4:30 pm, 5:00 pm

20th: 4:00 pm, 4:30 pm, 5:00 pm

-----Original Message-----
From: Maddox, Donald
Sent: Friday, May 08, 2015 11:06 AM
To: 'Julie Ufner'; Ben Husch; Melanie Condon; Judy Sheahan; Carolyn Berndt Ex. 4
Cc: Hanson, Andrew; Cook-Shyovitz, Becky; Richardson, Elena; Hannon, Arnita; Rupp, Mark
Subject: RE: Meeting Request

Alright - well we might be able to pull that off! I will shoot (EST) options to everyone on Monday for the entire week of the 18th that we can make work, and then see what happens.

Don

-----Original Message-----
From: Julie Ufner [Ex. 4
Sent: Friday, May 08, 2015 11:01 AM
To: Maddox, Donald; Ben Husch; Melanie Condon; Judy Sheahan; Carolyn Berndt (Ex. 4

Cc: Hanson, Andrew; Cook-Shyovitz, Becky; Richardson, Elena; Hannon, Arnita; Rupp, Mark
Subject: RE: Meeting Request

Hi Donald--

It depends when the meeting is... I might be able to make something work on the 18 or 19th but, just keep in mind I will be six hours behind EDT time.

Julie

-----Original Message-----
From: Maddox, Donald [mailto:Maddox.Donald@epa.gov]
Sent: Friday, May 8, 2015 10:48 AM
To: Julie Ufner; Ben Husch; Melanie Condon; Judy Sheahan; Carolyn Berndt Ex. 4
Cc: Hanson, Andrew; Cook-Shyovitz, Becky; Richardson, Elena; Hannon, Arnita; Rupp, Mark
Subject: RE: Meeting Request

Julie - If I run some options for the week of 18th and present them to everyone on Monday would you be able to call in to the meeting that week via conference line?

Don

-----Original Message-----
From: Julie Ufner [Ex. 4
Sent: Friday, May 08, 2015 10:43 AM
To: Ben Husch; Maddox, Donald; Melanie Condon; Judy Sheahan; Carolyn Berndt Ex. 6
Cc: Hanson, Andrew; Cook-Shyovitz, Becky; Richardson, Elena; Hannon, Arnita; Rupp, Mark
Subject: RE: Meeting Request

I have to echo Ben's comments--next week is tough.

The 12th I have no availability and Wednesday afternoon I have conference calls. Unfortunately, I leave town for a work trip the morning of May 14 and won't be back until May 26.

Julie Ufner
NACo

-----Original Message-----
From: Ben Husch Ex. 4
Sent: Friday, May 8, 2015 10:39 AM
To: Maddox, Donald; Julie Ufner; Melanie Condon; Judy Sheahan; Carolyn Berndt Ex. 4
Cc: Hanson, Andrew; Cook-Shyovitz, Becky; Richardson, Elena; Hannon, Arnita; Rupp, Mark
Subject: RE: Meeting Request

Don,

Next week is tough as its "infrastructure week" so I have a number of commitments already on the book. With that said, all 3 Thursday, May 14th times looks doable, but would prefer the 2pm start time. Thanks!

-Ben

Ben Husch
Committee Director, Natural Resources and Infrastructure Committee National Conference of State Legislatures
444 North Capitol St., NW Suite 515
Washington, DC 20001

Ex. 6
www.ncsl.org
Strong States, Strong Nation

-----Original Message-----
From: Maddox, Donald [mailto:Maddox.Donald@epa.gov]
Sent: Friday, May 8, 2015 10:28 AM
To: Ben Husch; Julie Ufner; Melanie Condon; Judy Sheahan; Carolyn Berndt Ex. 4
Cc: Hanson, Andrew; Cook-Shyovitz, Becky; Richardson, Elena; Hannon, Arnita; Rupp, Mark
Subject: RE: Meeting Request

Good morning to everyone. I apologize for the prolonged turnaround on this request. We have a lot of things happening here at EPA and we have been trying to narrow down schedules. So it looks like we have come up with 3 days for possibilities on our end next week. If none of these options work then we can shoot for the beginning of the following week. I have listed our availability below for everyone's review. If any of these work just let me know and I will be happy to set up the meeting. Just shoot me a note with your responses.

v/r

Don Maddox

(Start times assuming a 60 minute discussion)

May the 12th - 1:00 pm
May 13th - 1:00 pm, 1:30 pm
May 14th - 1:00 pm, 1:30 pm, 2:00 pm

-----Original Message-----
From: Rupp, Mark
Sent: Wednesday, April 29, 2015 9:55 AM
To: Maddox, Donald; Ben Husch; Julie Ufner; Melanie Condon; Judy Sheahan; Carolyn Berndt
Ex. 4
Cc: Hanson, Andrew; Cook-Shyovitz, Becky; Richardson, Elena; Hannon, Arnita
Subject: RE: Meeting Request

Don: We've expanded the circle a bit, also bringing in:
Judy Sheahan, U.S. Conference of Mayors; and Carolyn Berndt, National League of Cities.

Thanks,
Mark

-----Original Message-----
From: Maddox, Donald
Sent: Tuesday, April 28, 2015 4:47 PM
To: Ben Husch; Rupp, Mark; Julie Ufner; Melanie Condon
Cc: Marks, Teresa; Hanson, Andrew; Cook-Shyovitz, Becky; Richardson, Elena
Subject: RE: Meeting Request

Ben - I will throw some times/dates at you tomorrow after we have some items land on our end. We are pretty tight this week also so everything will be starting with next week. I will try to have that to you though by the end of the morning, tomorrow.

v/r

Don

-----Original Message-----
From: Ben Husch [Ex. 4]
Sent: Tuesday, April 28, 2015 3:12 PM
To: Rupp, Mark; Julie Ufner; Melanie Condon
Cc: Marks, Teresa; Maddox, Donald; Hanson, Andrew; Cook-Shyovitz, Becky; Richardson, Elena
Subject: RE: Meeting Request

Mark - Thanks for checking in on this. We'd love to get together, hopefully as one meeting. We are happy to host at our office as well as at NACo, whatever works best for the group.

Don - This week is pretty tight but next two weeks are more open, although we are unavailable on Tuesday the 5th. Thanks

Ben Husch
Committee Director, Natural Resources and Infrastructure Committee National Conference of State Legislatures
444 North Capitol St., NW Suite 515
Washington, DC 20001
202-624-7779
www.ncsl.org
Strong States, Strong Nation

-----Original Message-----
From: Rupp, Mark [mailto:Rupp.Mark@epa.gov]
Sent: Tuesday, April 28, 2015 7:55 AM
To: Julie Ufner; Ben Husch; Melanie Condon
Cc: Marks, Teresa; Maddox, Donald; Hanson, Andrew; Cook-Shyovitz, Becky; Richardson, Elena
Subject: Meeting Request

Hey, you three. Hope all is well.

Ex. 5

I'm asking Don to find an hour for us to meet with you.

Thanks!

Mark